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A SYNTHETIC SPEAKER.

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ABSTRACT.

This synthetic speaker is an electrical device manipulated by keys and levers for the production of synthetic vocal sounds and their combination into speech. The device was developed as an interesting educational exhibit by the Bell System at the San Francisco Exposition and the New York World's Fair.

From a buzzer-like tone and a hissing noise as raw material, the operator skillfully shapes speech by manipulating the controls to give inflection and the sound spectrum that differentiates one speech sound from another.

This paper covers the development of the device and the training of the operators to demonstrate it.

INTRODUCTION.

On January 5, 1939 there was demonstrated before the Franklin Institute a synthetic speaker.[1] Speech sounds were synthesized without the aid of the human voice upon manipulation of finger, wrist and foot controls by a young woman. These sounds with various inflections were combined to produce words and sentences intelligible to the audience. The occasion was the first public showing of a demonstration designed as a feature of the Bell System exhibit at the San Francisco and New York World's Fairs. This paper discusses the origin of this synthetic speaker and its development for exhibition purposes.

[1] U.S. Patent No. 2,121,142 shows an early conception of this device.

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The immediate background of this synthetic speaker is the large amount of fundamental work on the physical nature of speech which has been required for the most efficient application of Bell's invention, the telephone. After one believes he has a good understanding of the physical nature of speech, there comes the acid test of whether he understands the construction of speech well enough to fashion it from suitably chosen elements. The synthetic speaker demonstrated, which we have called the Voder,[2] was built in an attempt to answer this question.

On September 11, 1936 in connection with a talk [3] by Dr. Frank B. Jewett before the Harvard Tercentenary Conference of Arts and Sciences, one of the authors presented a demonstration of speech which had been analyzed electrically and then reconstructed or synthesized from electrical sources of energy.[4] In that system the energy for the synthesized speech was directly controlled by the speech of the original talker in the various demonstrations presented, although the speech was in many cases intentionally altered. For example, the synthesized speech was converted to a whisper or given a chanting effect or changed from a tenor voice to a bass voice or to a soprano voice, etc. The control of the synthetic speech in those demonstrations was by means of eleven electrical currents derived from the original speech. The basic distinction between the Voder and the apparatus demonstrated then is that with the Voder an operator controls the production of the synthetic speech purely by mechanical manipulation. Before proceeding with a more detailed description of the Voder some previous attempts to produce speech artificially will be reviewed briefly.

SPEAKING MACHINES OF THE PAST.

The first period in the history of speaking machines may be called the age of superstition and goes back to the ancient Greeks with their talking oracles. For the sake of impressing

[2] A synthetic word made up of key letters from "Voice Operation DEmonstratoR."

[3] "The Social Implications of Scientific Research in Electrical Communication," *Bell Telephone Quarterly*, October 1936; *Scientific Monthly*, November 1936.

[4] The functional elements of this system were described in an article in the *Bell Laboratories Record* of December 1936 by H. Dudley.

people with communication of apparently divine origin, long talking tubes were connected to the huge idols of their oracles such as the speaking head of Orpheus at Lesbos a few centuries B.C.

The second period starts a thousand years or more later and is characterized by the skill and ingenuity with which life-size "speaking heads" of wood and bronze were built, oftentimes with movable parts. Although the speaking tube was still used it was to make claims for mechanical ingenuity rather than for supernatural intervention. Well-known heads of this type were those of Pope Sylvester II, Albertus Magnus, and Roger Bacon.

The endeavor to imitate human speech by mechanical processes did not come until about 800 years later at the start of the third period which may be referred to as the scientific age. Chiefly by simulating the human mechanism as accurately as possible with bellows, vibrating reeds, etc., various devices were made for producing speech. The first one of these known to us was due to a Russian, Professor C. G. Kratzenstein, who constructed various shaped tubes to produce five vowel sound, a, e, i, o, and u. Professor Kratzenstein built his models because the Imperial Academy of St. Petersburg during the year 1779 offered its annual prize for the best answer to the two questions: first, as to what differentiates these five vowel sounds from each other and, second, as to whether they can be produced by mechanical models. The prize was won by Professor Kratzenstein. His five differently shaped resonant chambers simulated the vocal cavities for the sounds.

A few years later W. R. von Kempelen, of Vienna, carried this line of work much further and produced a number of consonant sounds as well as vowel sounds. He wrote a profusely illustrated book [5] discussing his work. Though obtaining a moderate amount of success he apparently never developed the device sufficiently far to distinguish the k-g and t-d sounds from the p-b pair. It is of interest to note also that the position of the left hand before a mouth-like opening was used to obtain the various vowel sounds.

[5] "Mechanismus der menschlichen Sprache nebst der Beschreibung seiner sprechenden Maschine"—1791.

In France at about the same time Abbé Mical built a speaking machine. Thus in three parts of the continent different men simultaneously worked with great vigor on the artificial speech problem in a way it had never been before.

These early efforts are interestingly described in a book review written by Sir Charles Wheatstone for the *London and Westminster Review*, October 1837, and included in his "Scientific Papers." He closed the article with a quotation from a contemporary writer, Sir David Brewster, "We have no doubt that, before another century is completed, a talking and singing machine will be numbered among the conquests of science." [6]

Since that time the interest has somewhat subsided, although a number of people have worked with devices along this line. In particular in recent years Sir Richard Paget has developed a large number of models for the different sounds and for successions of sounds. His book [7] describes these devices adequately. German engineers have also given considerable thought to the synthesis of speech.[8]

The first entirely electrical apparatus for producing speech sounds by manual operation, so far as known to the authors, was that of J. Q. Stewart [9] constructed in 1922 when he was with the Development and Research Department of the American Telephone and Telegraph Company. Similar apparatus was demonstrated by Dr. Harvey Fletcher of the Bell Telephone Laboratories before the New York Electrical Society in February 1924 when he produced a limited group of sounds including some vowels and the words "mamma" and "papa."

These developments, so briefly noted here, have shown an ever increasing understanding of the mechanism of voice. With communication by speech as one of man's most distinguishing characteristics and with the role played by it in man's social development so tremendously important it is not

[6] "Letters on Natural Magic," 1832.

[7] "Human Speech."

[8] For example, "Ein Neues Elektrisches Sprechgerät zur Nachbildung der Menschlichen Vokale." Karl Willy Wagner. Abhandlungen der Preussischen Akademie der Wissenschaften, 1936.

[9] "An Electrical Analogue of the Vocal Organs," *Nature*, 110, September 2, 1922, pp. 311–12.

unnatural that he should devote considerable time and energy to the study of the voice mechanism by all the various possible methods he can devise.

The Voder Mechanism Compared to That of the Human Voice.

The Voder mechanism will next be compared along broad functional lines to that of man for producing speech. The Voder has no outward resemblance to the speech organs of man. By no stretch of the imagination can one see lips, tongue, larynx or lungs in the Voder itself shown in Fig. 1 as demonstrated at the Franklin Institute. The internal resemblance is no closer when the circuits are seen as in Figs. 2, 3, and 4 for the finger keys, the console-mounted control apparatus and the energy-handling equipment, respectively.

However, functionally the Voder and the speech mechanism must be alike. This functional similarity of the different parts is illustrated in Fig. 5. There are three more or less distinct steps in the production of speech by man: first, providing an energy source in the form of compressed air in the lungs; second, converting energy from this steady source into regular or irregular vibrations at rates audible to the human ear; third, selecting from these audible vibrations by resonance methods to obtain the proper spectra for the various speech sounds.

Corresponding to the steady energy supply of the lungs, the Voder derives its steady energy flow from an electrical supply.

For the second step of speech production in the case of the human voice the conversion of the compressed air stream from the lungs into audible energy is carried out by two distinct methods. In the first a buzzer-like sound is produced by the vibration of the vocal cords in the larynx or voice box of the speaker. This method is used in producing a voiced vowel such as e (as in be). In the second a hissing sound is produced by forcing a stream of air through a constriction formed at some point in the vocal tract. This method is used in whispering and in producing an unvoiced fricative consonant such as s (as in see). Both of these methods are used simultaneously in producing voiced fricative consonants such as z (as in zoo).

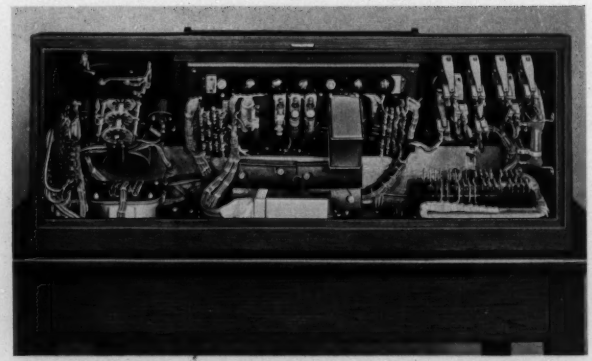
FIG. 1.

The Voder as demonstrated by Mrs. Harper at The Franklin Institute.

FIG. 2.

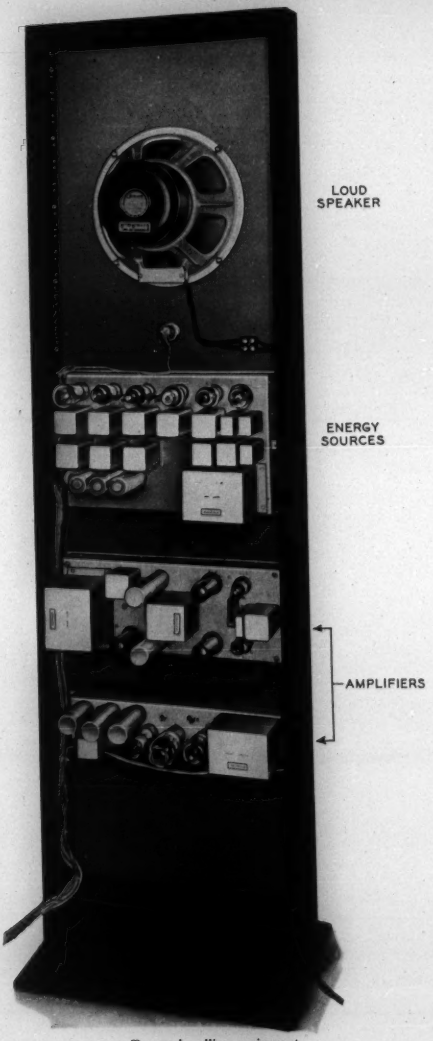
Finger key circuits.

FIG. 3.



Console-mounted control apparatus.

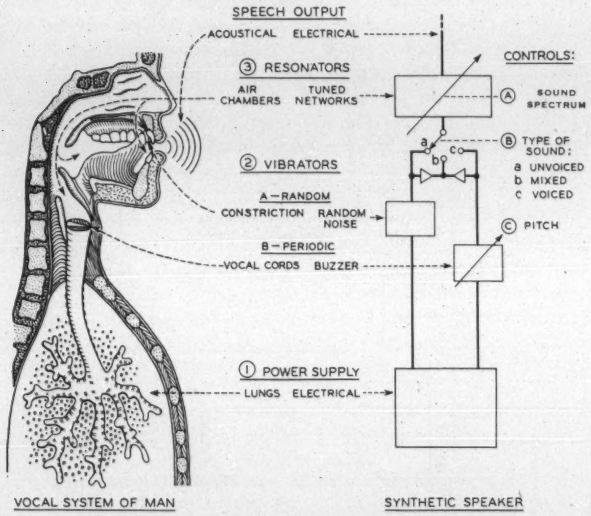
FIG. 4.



Energy-handling equipment

With the Voder, analogous processes are carried out as shown at the right in Fig. 5. Corresponding to the vocal cords which produce the buzzer-like sound there is an electrical oscillator labeled "buzzer" that produces a steady buzzer-sounding tone. The fundamental frequency of this buzzer

FIG. 5.



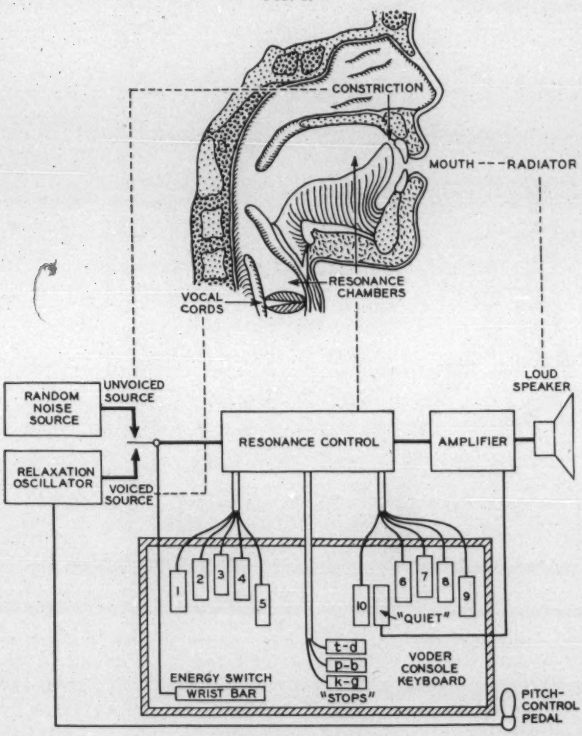
Functonal comparison of synthetic speaker with the human vocal system.

tone can be varied to correspond to the change of pitch of the human voice. Corresponding to the constrictions in the vocal passages from which are made the unvoiced sounds the Voder contains an electrical "random noise" source which by itself produces a continuous hissing sound.

The third and final step in speech production is that of selecting from the many vibration rates produced by these energy sources those needed to form the spectrum of the phonetic element desired at the moment. This process is carried out in the vocal system of man by adjusting the reso-

nances and couplings of air cavities through movements of the lips, tongue, jaw, etc. In the case of the electrical mechanism this objective is attained by means of selective networks in the

FIG. 6.



Essential parts of the Voder.

form of simple electrical filters the outputs of which are controlled by 10 potentiometers manipulated by the fingers. In synthesizing speech sounds these finger controls are supplemented by a foot control for changing the fundamental fre-

quency of the electrical oscillator (voice pitch change) and a wrist bar for switching between voiced and unvoiced energy sources. These controls correspond to those operated electrically in the all-electrical analyzer-synthesizer demonstrated at the Harvard Tercentenary. As will appear later certain speech sounds proved difficult for the manipulative skill of the operators with the result that some added special controls were provided.

Summarizing, we see that the Voder is an assemblage of telephone apparatus that enables a human operator, by manipulation of fingers, wrist and foot, to build up speech sounds similar to those produced by the human vocal tract.

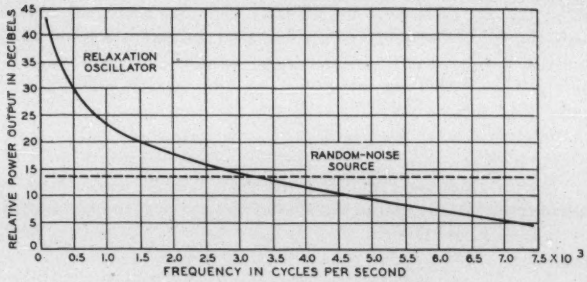
For a more detailed description, Fig. 6 shows the positional and functional relations of the apparatus and its controls. These will be discussed under three headings: the vibratory energy sources for the synthetic speaker, the resonance controls for shaping the speech sounds, and the simplifying controls. The energy sources are shown at the left as consisting of a random noise source and a relaxation oscillator. The heavy connecting lines running via the resonance control and amplifier to the loud speaker show the path of energy flow while the light connecting lines from the Voder console keyboard to the main circuit indicate connections from the mechanically actuated members. The dotted lines to parts of the head indicate those voice correspondences more fully discussed in connection with Fig. 5.

THE VIBRATORY ENERGY SOURCES FOR THE SYNTHETIC SPEAKER.

The source of vibratory energy used for producing the hissing noise needed in forming the synthetic whispered speech and the unvoiced consonants is a noise of purely random fluctuations. Such a source has an energy distribution uniform over the frequency band as indicated by the horizontal dotted line of Fig. 7. The sound produced is a hiss, somewhat similar to that produced by steam escaping from a radiator. The first electrical source employed for such a random characteristic was amplified thermal or resistance noise.[10] Later a simpler arrangement involving much less

[10] "Thermal Agitation of Electricity in Conductors," J. B. Johnson, *Phys. Rev.*, July 1928.

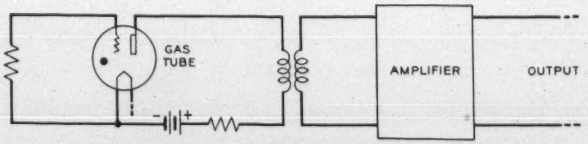
FIG. 7.



Output characteristics of energy sources in the Voder.

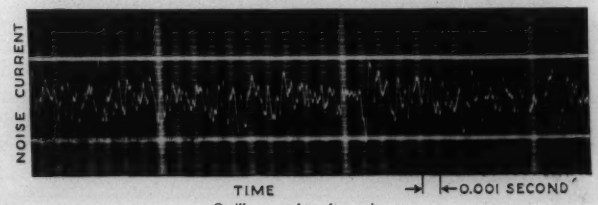
amplification and, so, better stability was secured by using the random fluctuation in ionic current in a gas-filled triode with the circuit shown in Fig. 8. The oscillogram of Fig. 9 shows the random character of the output from this circuit. The turbulences in the air escaping through constrictions formed in the vocal passages have much the same type of random characteristic.

FIG. 8.



Circuit for obtaining random noise.

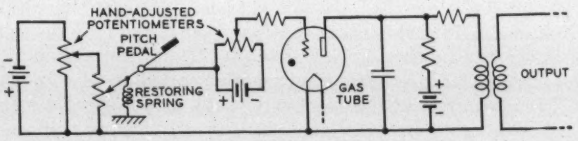
FIG. 9.



Oscillogram of random noise.

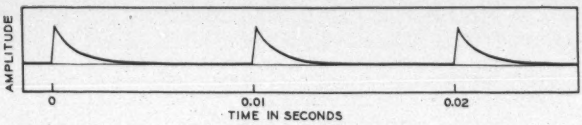
The source of energy employed for producing the buzzer-like tone needed for synthetic voiced sounds is a form of relaxation oscillator, as shown in Fig. 10. Its output is the typical repeated damped pulse illustrated in Fig. 11 for a

FIG. 10.



Circuit of relaxation oscillator.

FIG. 11.



Output wave of relaxation oscillator.

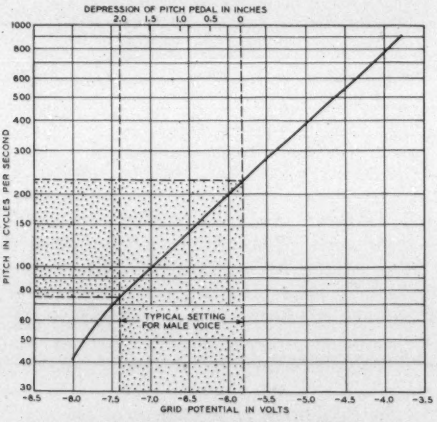
fundamental frequency of 100 cycles per second. Such a wave, as is well known, consists of a fundamental and numerous upper harmonics. The power distribution is shown by the solid line of Fig. 7 from which can also be observed the relative amounts of power at any given frequency for the two types of sound as used in the Voder, with equal power found at about 3200 cycles. More precisely at around 3200 cycles the power in a single harmonic frequency is the same as the average power in a frequency band of the random noise equal in width to the fundamental frequency of the voiced sound synthesized.

The sound produced by the relaxation oscillator is buzzer-like. It has a definite pitch which gives a somewhat musical sound not found in random noise. The pitch can be varied by the Voder controls to simulate the full range of human voices with their inflections. The circuit of Fig. 10 shows three potentiometers which vary the grid potential on the gas tube for this control. Two are for preliminary adjust-

ments by hand and the other is a pedal control operated by the right foot for the instantaneous pitch value desired. The two hand adjustments are made to set the bottom frequency and the octave range available above this bottom for the particular voice produced. This determines whether the synthetic voice is bass, soprano or intermediate in character and the range of the voice in octaves. Finally the pedal pitch control is used in the operation of the Voder for inflection in the speech produced, thus giving it life and expression. If the pitch pedal is left in a fixed position articulate speech will still be produced but the effect is that of a monotone chanting.

The relation between the pitch of the output and the position of the pedal is shown quantitatively in Fig. 12 for

FIG. 12.



Pitch characteristic of relaxation oscillator.

simulating a typical male voice. Pitch is plotted against grid potential and against the deflection of the spring-actuated pedal controlled by the toe of the operator's right foot. When he lowers his toe the pitch of the Voder voice is lowered and when he raises his toe the pitch is raised. The spring always returns the pedal to the "up" position when the toe is raised. Figure 12 shows that the logarithm of the fundamental fre-

quency is approximately proportional to the depression of the operator's toe. This means that equal changes in depression of the toe any place in the operating range produce equal fractional parts of an octave change in the pitch of the Voder voice. This makes the production of pitch change correspond to the way in which the ear interprets pitch change. Equal fractional parts of an octave change in pitch are judged by the ear to be equal musical intervals.

Referring to Fig. 6, it is seen that the operator has available on his keyboard a switch for selecting either the voiced or unvoiced energy sources. This switch is in the form of a horizontal bar associated with a pair of contacts and is controlled by the operator's left wrist. When the bar is depressed by the wrist, the voiced energy source is selected and when it is raised by its restoring spring the unvoiced energy source is selected. In producing some speech sounds such as "zh," both voiced and unvoiced energy are obtained simultaneously by switching means to be described later.

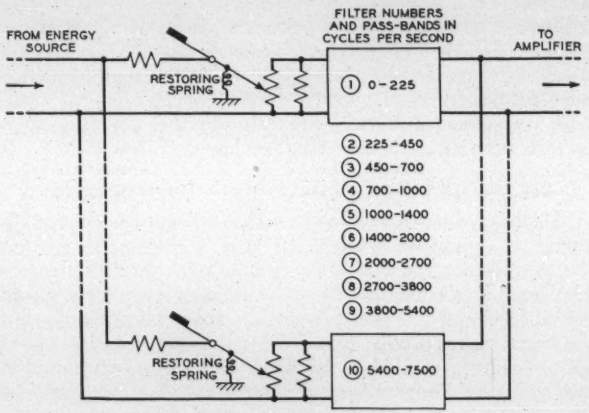
THE RESONANCE CONTROLS FOR SHAPING THE SPEECH SOUNDS.

Preliminary to describing next the resonance control of the Voder, it should be pointed out that if the electric output waves of either the voiced or unvoiced energy sources were converted into acoustic waves by a loudspeaker they would not be recognized as speech sounds. It is also probable that the sound waves produced by the human voiced and unvoiced energy sources would not be recognized as speech sound if they could be divorced from the resonant effects produced by the cavities and apertures of the mouth, throat, and nose. The mass and elasticity of the air in these cavities resonate in such a fashion that certain groups of overtones in the voiced wave produced by the larynx are radiated into the atmosphere more efficiently than are others, being thus "reinforced" in popular language. This means that when a voiced speech sound is spoken the wave from the larynx has its spectrum determined by the configuration of the throat and mouth so that the tone quality characteristic of the particular speech sound is radiated. In the production of an unvoiced speech sound a corresponding process takes place.

In order for the Voder to shape speech sounds from what

might be called the raw material furnished by the voiced and unvoiced energy sources, an electric circuit must be adjusted so that when the electric wave from either energy source is passed through it, the spectrum of the wave is properly fashioned. This resonance control circuit must be capable of being adjusted by the operator so that the spectrum characteristic of each speech sound can be simulated to a sufficient precision. As indicated in Fig. 6, the resonance control is effected by the finger-operated keys numbered 1 to 10 conveniently situated on the Voder keyboard. The actual resonance control

FIG. 13.



Circuit for resonance control.

circuit is shown in Fig. 13. The band of frequencies used by the Voder in producing speech has been chosen extending from 0 to 7,500 cycles per second. This band has been divided into 10 sub-bands, each sub-band being represented in the resonance control circuit by a band-pass filter. The band of frequencies passed by each filter is indicated in Fig. 13. Each filter readily passes waves whose frequencies lie within its pass band and attenuates waves of other frequencies. The pass bands of these filters were chosen after a study of analyzed speech sounds and the data available on how the human ear interprets these speech sounds.

The amplitude of the electric wave from either the voiced or unvoiced Voder energy source that is applied to the input terminals of any filter is determined by the position of the movable arm of its potentiometer as shown in Fig. 13. The potentiometers are placed ahead of the filters so that the effect of any non-linear distortion at the potentiometers is filtered out in large part. Each potentiometer is controlled by the depression of the corresponding control key situated on the Voder keyboard. A spring returns each key when released to its "up" position in which position no voltage is applied to the input of its filter. As the key is depressed a small voltage comes on which increases approximately logarithmically with further key displacement over a range of 15 db. The operator is thus able to control the spectrum of the wave issuing from the Voder energy sources in a manner analogous to that by means of which the configuration of the mouth and throat controls the spectrum of the sound shaped from the human vocal energy sources, with the fingers of the operator operating the keys at the rates used by the tongue, lips, etc., in producing speech sounds.

The resonance control keys were designed to give logarithmic increases in amplitude for equal increases in depression because the ear interprets logarithmic increases in amplitude of a sound wave as approximately equal increments in loudness. These control keys must be operated rapidly and with a very light touch in order that the operator may rapidly and smoothly make the changes in key depressions necessary for producing a succession of speech sounds.

Thus far it has been shown that the Voder has an electrical voiced and unvoiced energy source, the pitch of the former being controlled by the position of a pitch pedal. Operation of the wrist-bar switch selects the desired energy source and passes its output wave on to the resonance control circuit where its spectrum is fashioned into that of the desired speech sounds by the depression of 10 resonance control keys. After passing through the resonance control circuit, the electric waves constituting the Voder speech sounds are amplified to a sufficiently high level so that they can be radiated from a suitable loud speaker at the proper volume for a large audience.

THE SIMPLIFYING CONTROLS.

In order to simplify the operating technique several special controls and interlocking operations were added. One type of interlock has been applied to some of the resonance control keys. The naturalness of certain vowels which require the depression of resonance control key No. 3 or No. 4 such as a (as in father) is enhanced if a small amount of the fundamental frequency of the Voder voiced energy source is used. The fundamental frequency usually passes through filter No. 1. Hence a connection has been made from keys No. 3 and No. 4 to key No. 2 through high resistance networks so that when either of these keys is depressed a small voltage is introduced across filter No. 1. This means that a small flow of energy at the fundamental frequency is automatically passed on to the loud speaker whenever key No. 3 or No. 4 is depressed without the necessity of the operator depressing key No. 1.

A special interlocking feature of the Voder as at present arranged reduces the volume as the pitch is lowered. This is characteristic of man as he talks. In English speech at the end of a sentence, one usually drops his inflection and drops his volume down to nothingness at the same time. This feature is particularly helpful in the Voder because it suppresses an unpleasant gliding inflection that often occurs otherwise that resembles somewhat the normal inflection in the word "woomp."

Another control switch enables the operator to produce whispered speech. Whispered speech uses only an unvoiced energy source. The whispering switch is arranged so that when it is in the whispering position the unvoiced energy source is always selected no matter what the position of the wrist bar. This means that using the same operating technique the operator can make the Voder speak with either a normal voice or a whispering voice depending on whether this switch is in the normal or whispering position.

Another special control is known as the "quiet" key. This is desirable because the understanding of the four speech sounds f (*f*un), v (*v*an), th (*th*in), and *th* (*th*en) is lessened, if they are made too loud.[11] The depression of the "quiet" key

[11] The decrease of articulation at high energy level is shown graphically in Fig. 133, page 276 of "Speech and Hearing" by Harvey Fletcher.

by the operator's right thumb introduces a decrease in amplitude of the speech waves of about 20 db. By depressing the "quiet" key at the same time that the resonance keys are depressed, the resulting speech sound is produced at the proper loudness level.

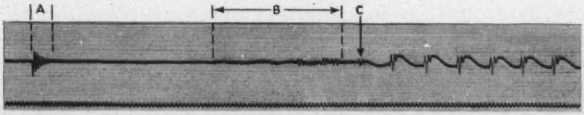
The means provided to the operator for producing speech sounds such as zh that use both types of vocal energy is another special automatic control. Since in the Voder production of the sounds using both types of vocal energy, either resonance control key No. 8 or the "quiet" key is depressed, a contact is provided on these two keys so that if either is depressed with the wrist bar down, the unvoiced as well as the voiced Voder energy source is selected for forming the speech sound.

The speech sounds classified as stop consonants are of an explosive nature involving sudden changes in amplitude. When these sounds are produced by the motion of the 10 resonance control keys, the operator must move his fingers rapidly. This is a considerable change in operating technique from that for producing other speech sounds, where a gliding motion is used. Accordingly, a set of three stop consonant keys has been provided on the Voder keyboard for producing the stop consonants by the right thumb of the operator with the usual gliding motion. Each of these keys assists in producing a pair of stop consonants, the first of each pair being unvoiced and the second its voiced conjugate; one key is for k and g, one for p and b, and the third for t and d. For the fourth pair of stop consonants, ch (*ch*urch) is produced by making sh so suddenly as to give an explosive effect while j (*j*udge) is produced in the same way but with a small amount of voicing in the early part.

The sequence of effects occurring when one of the stop consonant keys is depressed is illustrated in Fig. 14, which shows an oscillogram of the beginning of the word "key" as produced by the Voder. To produce this word the wrist bar, the k stop consonant key, and the proper resonance control keys are depressed simultaneously. The first operation the stop consonant key performs is the removal of the voiced energy source from the input of the resonance control filters. Further depression of the k key discharges a condenser in a

resonant circuit which causes the initial damped oscillation shown at A. This corresponds to the miniature explosive impulse or click initiated in the mouth of a speaker when the

FIG. 14.



Oscillogram showing the beginning of the word "key" as produced with the Voder. (A 1000-cycle timing wave is shown at the bottom.)

air-tight seal between the tongue and the hard palate is broken at the beginning of the sound k. As the k key is further depressed there is an interval of silence, then the unvoiced energy source is connected to resonance control filter No. 7 to produce a spurt of noise, B. Soon thereafter the stop consonant key reaches the bottom of its stroke connecting the voiced energy source to the input of the resonance control filters as at point C. By this time the resonance control keys required to produce the ē sound of "key" are almost fully depressed and the vowel starts suddenly at almost full amplitude. After the released k key is restored by a spring to its initial position, the condenser is again charged so as to be ready to produce another k. By depressing the k key in about 1/2 or 1/3 the time required to produce k, a g (as in go) is produced. The sequence of operations for the t-d and the p-b keys are similar to those for the k-g key except that different timings and different resonance control filters are used. However, the p-b key produces no initial damped oscillation, as this is unnecessary for these sounds.

By throwing another switch the operator of the Voder can cause the fundamental frequency of the voiced energy source to fluctuate two or three per cent at the rate of 6 times per second to give a wavering voice as in an old person. This is done by impressing a small voltage fluctuating at the rate of 6 cycles per second in series with the grid voltage of the relaxation oscillator.

Although in many ways the Voder has been designed to perform operations analogous to those performed by the

human vocal tract in producing speech sounds, in some respects it can do things that the voice can not do. Not only can this device cover the full range of human vocal organs from bass to soprano but it can be used for the imitation of animal sounds and of sounds of a mechanical origin. The sounds of this sort demonstrated at the Franklin Institute included imitations of a cow, a pig, a woodpecker, various insects, an airplane, and the steam engine of a train.

The discussion proceeds next to operating features. From the operating standpoint there were three rather definite steps that overlapped to some extent:

(1) Making the Voder talk.
(2) Selecting and training personnel.
(3) Planning the World's Fair program.

MAKING THE VODER TALK.

In the creation of a piece of apparatus of this kind there comes a time when the electromechanical design cannot advance without the development of a technique of operation. From that point the two must proceed hand in hand, each serving as a guide to the steps taken by the other.

In the development of the Voder there were certain decisions that obviously could not be made until at least a provisional technique of operation had been established. These decisions related to questions of the following nature. What is the best spatial arrangement for the finger keys? How much movement should the keys have? By what means should the switching between the sound sources be done? How should the pitch be varied, and over what range? What mechanical characteristics should each control have?

The answers to such questions could not be given until after a good deal of exploratory work in the operation. In each case the solution embodied in the final design, as described earlier in this paper, was calculated to provide as simple an operating technique as possible without restricting the freedom of the operator to take advantage of the possibilities of the instrument.

As the operating technique developed, certain provisions were found desirable that had not been anticipated, for

example the volume reducing key, the arrangements for mixing voiced and unvoiced sounds, the special keys for facilitating the production of stop consonants, and the reduction of volume with lowering of pitch.

At the outset, a study was made of the information about speech sounds that was already available and oscillographic measurements were made of the way in which speech sounds would divide themselves among the ten filter channels that were to be used as the basis for the Voder.

It was found that the information so obtained, while it was useful in many ways, was so complex that it was almost impossible to apply it in its entirety in working out the Voder technique. Simplification, at any rate at the start, was necessary, and it became apparent that the most fruitful method of attack was to search for the desired sounds by manipulation guided by the ear.

After a speech sound had been made with some degree of success it was usually found on referring back to the oscillographic data that agreement, as far as the predominating resonances were concerned, was strikingly good. However, any attempt to introduce the minor features of the oscillographic record on the Voder keyboard always resulted in complete lack of success.

There were certain sounds that refused to fall into line. This was particularly true of those vowels which have marked low frequency resonances, such as "$\overline{oo}$," "$\overline{aw}$," and "$\bar{e}$." It was found necessary to use a much lower resonance when producing these sounds on the Voder than was indicated by previous data.

A great deal of practice is necessary to make even the simpler sounds well, and there was in consequence always a period of uncertainty about any sound. This was particularly noticeable in connection with a series of articulation tests that was made during the exploratory period. Sounds which were frequently misunderstood in the tests were, after extended practice, made with a fair degree of certainty by the same operator.

SELECTING AND TRAINING PERSONNEL.

By the fall of 1937 the operational technique was advanced far enough to permit of planning a course of instruction for

potential operators, and some tentative moves were made towards finding out what types of persons would be suitable as operators.

Before the end of 1937 it had been decided that Voder operators for the World's Fairs should be drawn, if possible, from among telephone operators, and for that reason the search for operators has been confined to that field. The results have justified the hope that operators drawn from this source would be able to acquire sufficient skill, in the limited time available, to meet the needs of the World's Fairs exhibit.

It would have been interesting to see whether operators taken from groups talented along different lines, such as musicians, sculptors and actors, would have exhibited greater skill or developed it more rapidly. At present the most that can be said as to the requirements for a Voder operator are that they include a quick intelligence, the ability to control the fingers independently of one another, and a good ear. There is some evidence that skill acquired in such finger techniques as are used in typewriting and stenotypy is of no value but rather a drawback.

When the instruction course was planned it was impossible to do more than guess how long it would take an operator to master the technique of the Voder well enough to put on a performance at the World's Fair which was to open in about a year and a half. The course was therefore planned to be as simple as possible and an attempt was made to avoid words that experience had shown to be very difficult. However it was felt that the course must cover all speech sounds and nearly all their combinations if it was to provide adequate training even for a very simple public performance.

Recourse was had to three published vocabularies; the words most frequently used in telephone conversations,[12] Dewey's list of words most frequently used in English,[13] and the system known as Basic English.[14] With these as a basis a vocabularly of about 2500 words was drawn up. These were classified according to their phonetic content. Finally they were arranged in the order in which it seemed, from ex-

[12] "The Words and Sounds of Telephone Conversations," N. R. French, C. W. Carter and W. Koenig, *Bell System Technical Journal*, IX, 290–324.

[13] "Relativ Frequency of English Speech Sounds," 1923.

[14] "The System of Basic English." C. K. Ogden, 1934.

perience gained in finding out how to form them, that the various sounds should be learned on the Voder.

It was decided that about twenty-four operators would be needed to supply the requirements of the Golden Gate Exposition at San Francisco and the New York World's Fair and provide a reservoir in case of sickness or other casualties. In selecting these, about three hundred and twenty switchboard operators were tried, the majority from the New York Telephone Company and the rest from the Long Lines Department of the A. T. & T. Co.

In each case the method of first trial was to see whether the candidate could, in the course of about half an hour and with such instruction as was necessary, produce a short simple sentence. Candidates were graded as to their fingering ability, phonetic sense, quickness of comprehension, and so on.

About twenty per cent were selected for a second trial which usually took place a week or so after the first. In the second trial a more difficult sentence was essayed including a word requiring skill in inflection. About thirty girls were judged to have passed this trial well enough to warrant receiving further attention and out of these the final twenty-four were picked.

Consideration was given to various methods of training, included among which were touch methods using templates to guide the fingers, and visual methods using indicators, but it was concluded that training by ear was the most practical method of training, as the ear had been the most reliable guide in the exploratory work. All the training has been done by individual instruction, including demonstration by the teacher.

In order to train two dozen operators at the same time, it was necessary to have twelve Voders of which ten were set up in small acoustically treated rooms for practice. Each girl spent about six half hour periods at the machine daily and was given a lesson every other day. It was found that this was about all an operator could stand without getting too fatigued.

With this schedule of training, about six months served to carry the instruction through the course of 40 lessons. Most pupils could in fact at the end of about four months carry on a simple conversation on the machine though with no great

intelligibility. Generally speaking it seems to take about a year to develop a good technique, the first half spent in acquiring the ability to form any and all sounds, the second half being devoted to improving naturalness and intelligibility. The technique of the pitch pedal plays a much greater part in the work of the second half year and is most important to intelligibility.

During the training period solo practice was assisted by the use of recording machines of the magnetic tape kind. These enabled the pupils to hear their own results in a much more objective way than was possible by listening while forming the sounds.

At certain stages in the training the operators were allowed to carry on conversations with each other on the machines. This was provided for by coupling the outputs of the machines in pairs. This can be overdone however. While it provides excellent practice and is most useful in building confidence, too much of it is apt to lead to careless technique because the listener becomes expert at interpreting badly formed words and ceases to be critical.

PLANNING THE WORLDS FAIR PROGRAM.

In the Telephone Company's exhibit at the New York World's Fair the Voder will be displayed in a large circular room, about eighty feet in diameter, with a balcony extending about three quarters of the circle. A similar type of presentation will be made at the Golden Gate Exposition. The Voder will be on a platform jutting out from the wall and raised just above the heads of the audience on the main floor. There will be no seats, members of the audience entering and leaving the hall at any time.

Since we shall be dealing with a continually changing audience it is judged necessary to provide a continuous performance which will repeat itself every five or six minutes, about as long a time as the average visitor can be expected to pay attention to a single exhibit.

The short time available for training the operators and the differences in ability among them make it desirable to limit the performance to fairly simple sentences. This can best be done by presenting the demonstration in the form of a dia-

logue; and this will be the nature of the World's Fair show, the dialogue being carried on between a man with a microphone standing beside the Voder and the Voder itself worked by one of the girl operators.

This method provides also a means of "cueing" some of the words to be said by the Voder, a precaution which is important since the performance is to be presented to an unprepared audience who will be hearing, for the first time, speech produced in a voice with an unusual quality and with unavoidable imperfections in delivery. When we remember how difficult it is at first to understand what is said by a foreigner with an imperfect command of our language we can appreciate the necessity for assisting comprehension.

The performance will be in the form of a prepared script. It would of course be more spectacular if the audience were invited to participate, for example by suggesting words to be made or by asking questions, and this could no doubt be done with some measure of success. However, because of the large crowds which are expected to pass through the Voder room, this appeared to be impractical.

For the same reason, and also because the Voder is being presented purely as a machine for making synthetic speech, it is not our intention to include such things as singing, animal sounds or inanimate effects, although a wide range of these can actually be produced by a skilled operator.

In conclusion, a word of appreciation should be expressed to the many other people in the Bell System whose efforts are represented here in varying degrees. This speaking machine would not be possible were it not true that many specialists in addition to the authors have contributed to many parts of it from their own store of knowledge. Back of the present development lies a great mass of fundamental speech study by other people. Important use has been made of many types of apparatus basic to modern telephony. From the specially designed finger controls to the loudspeaker used to project the sound that will be heard, it is only by the coöperation of many specialists along different lines over a period of many years that a satisfactory speaking machine becomes possible in a physical embodiment as is now presented in the form of the Voder. Finally, great credit is due to the operating group for mastering a very difficult operating technique.

CLOUD CHAMBER STUDIES OF COSMIC RAY SHOWERS AND PENETRATING PARTICLES.[1]

BY

J. C. STREET, Ph.D.,

Harvard University.

In his lecture at the Harvard Tercentenary meetings, September 1936, Professor R. J. Oppenheimer presented a very strong case for the complete validity of the quantum electrodynamic theory as applied to the processes of radiation and pair formation by high energy electrons and photons. The bases for this renewed belief in a theory which at one time had been more or less abandoned,[2] were twofold. (1) The energy losses in lead of cosmic ray shower electrons with energies up to some 300 MEV had just been shown to be in close agreement with the theoretical predictions,[3] and (2) the major shower phenomena could be beautifully described in terms of the multiplicative processes of successive radiation and pair formation.[4] Oppenheimer's stand, however, was faced by several serious objections. The test of the theory of radiative losses by direct measurement of the energy losses of shower particles up to 300 MEV could not be regarded as conclusive for it was entirely reasonable to assume that the breakdown in the theory occurred at somewhat higher energies and in fact this view was held by Blackett and Wilson in their paper of May, 1937.[5] Also, the success of the theory in describing the shower phenomena was of a qualitative sort lacking sufficient quantitative comparison to make it entirely convincing. Indeed no very good evidence existed at that

[1] Based upon a paper read at the Chicago Cosmic Ray Symposium, June 29–30, 1938.

[2] J. R. Oppenheimer, *Phys. Rev.*, **47**, 44 (1935); L. W. Nordheim, *Phys. Rev.*, **49**, 189 (1936).

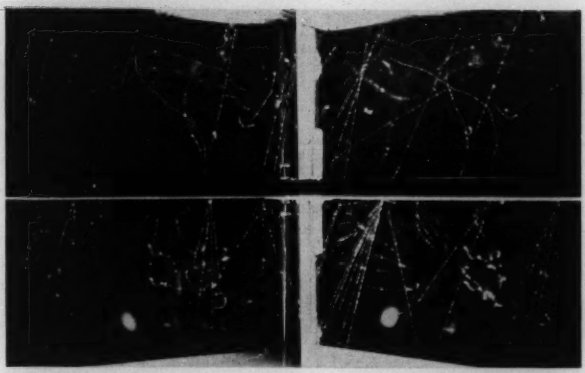
[3] Anderson and Neddermeyer, *Phys. Rev.*, **50**, 265 (1936).

[4] This argument was later presented in more complete form by Carlson and Oppenheimer, *Phys. Rev.*, **51**, 220 (1937).

[5] Blackett and Wilson, *Proc. Roy. Soc.*, **160A**, 304 (1937).

time to show that the fundamental processes of shower growth corresponded at all to the successive stages of multiplication by radiation and pair formation. It is true that some of the shower photographs available gave tentative evidence in favor of the multiplicative hypothesis in showing that several "centers" often appeared simultaneously. Fig. 1 is an example of this type. On the other hand, many of the photos seemed to show the divergence of many rays from a point as though the showers were often of the explosion type. How

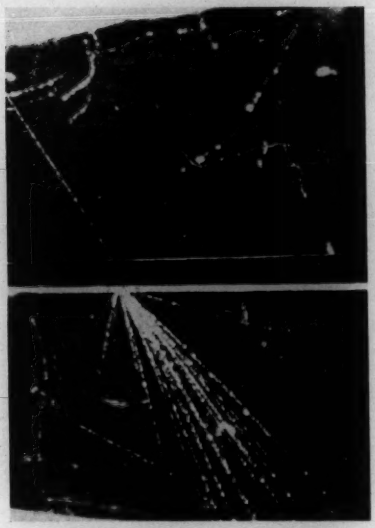
FIG. 1.



A case in which several groups of shower particles are produced simultaneously in a 1.3 cm. lead plate. The individual groups, however, seem to diverge from "points" in the plate.

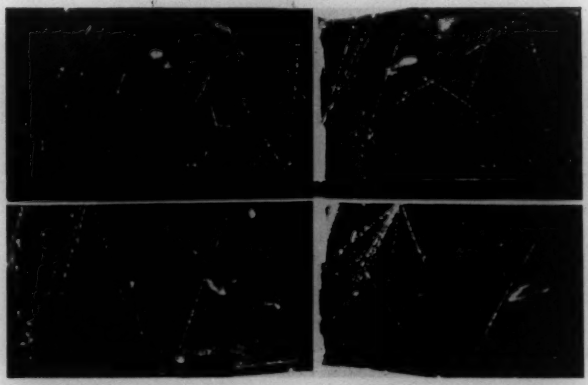
strong this evidence seemed can be seen by reference to Figs. 2 and 3. Furthermore, it was hard to understand the growth of showers of considerable size in rather thin layers of material if the process was entirely one of successive multiplication with free paths for radiation and pair formation a considerable fraction of the total thickness. Fig. 4 is an example of the development of a shower of some 50 rays in 1.3 cm of lead. As an additional complication some dense tracks characteristic of heavy particles had been observed in some of the showers. Showers of this sort could not be described in terms of the theory and had to be arbitrarily segregated from the usual

FIG. 2.



A shower which gives the misleading impression of origin at a point.

FIG. 3.



A photograph similar to Fig. 2, except that the shower is initiated by a photon. These are typical examples not special cases.

showers and treated as a different sort of phenomenon. No clear evidence showing the relative importance of showers of this type existed at that time.

Faced with these uncertainties we were not ready to accept the multiplicative theory of showers without some further experimental check. At my suggestion Mr. Lewis Fussell [6]

FIG. 4.

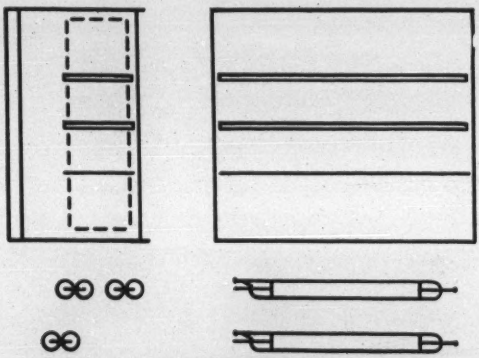
A fairly large shower develops within 1.3 cm. of lead.

had already begun an experiment to observe in more detail the nature of the shower building process. The arrangement of his apparatus is shown in Fig. 5. The cloud chamber contains three layers of lead of thickness .63 cm., .63 cm. and .07 cm. respectively from top to bottom. The appearance of the showers as they develop in such plates should clearly dis-

[6] Fussell's work was first reported at the April Meeting of the American Phys. Soc. 1937, *Phys. Rev.*, **51**, 1005 (1937).

tinguish between the multiplicative and explosion processes. In the winter of 1936–37 Fussell photographed 2,000 showers with this arrangement and his study of these leaves little doubt that the principle shower process is one of successive multiplication. The reader can best reach this conclusion for himself by inspection of the typical examples shown in Figs. 6–13. A more rigorous and quantitative proof of this conclusion comes from a consideration of the collision phenomena in the thin bottom plate. At least one in nineteen of the explosion type of shower should have its center in this plate

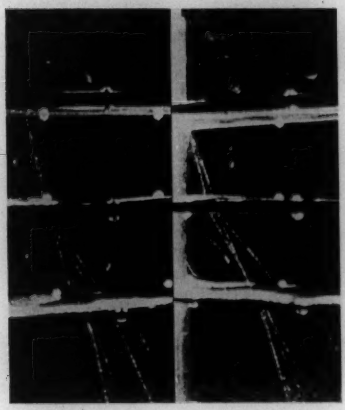
FIG. 5.



The arrangement of apparatus for the study of shower processes. The cloud chamber is expanded immediately following a coincident discharge of the Geiger counters.

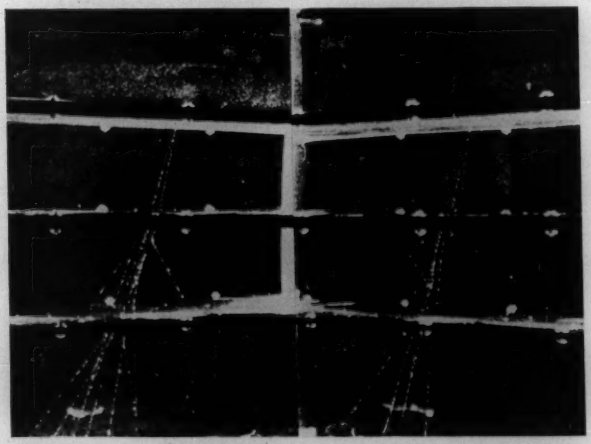
since the thickness is this fraction of the total. Multiplicative showers with "apparent centers" in this plate would not be expected since its thickness is small in comparison with the free paths for radiation and pair formation. In the 2,000 shower photos, 1,200 with the thin plate below and 800 with it above, there were just two cases of more than a pair from a "point" in the thin test plate. One of these is obviously an explosion shower and is shown in Fig. 18. The other, a four ray group, occurred when the plate was below and may have been due to pair formation by two close photons from a shower above.

FIG. 6.



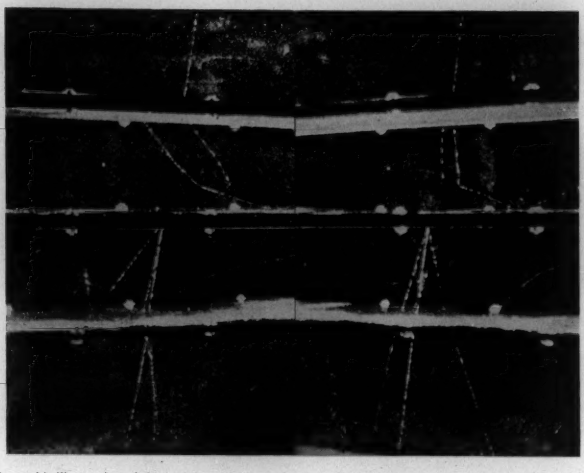
A small shower which illustrates multiplication in successive stages. The bottom plate is the thin sheet, 0.07 cm.

FIG. 7.



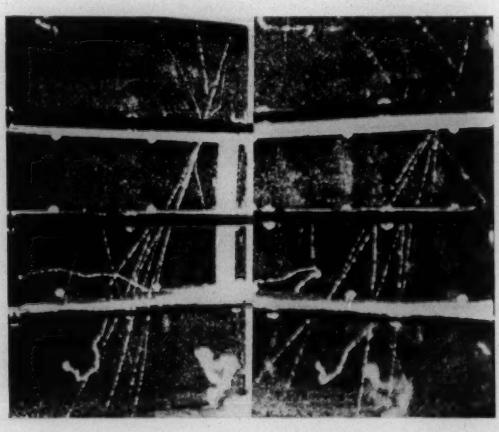
Multiplicative growth of another small shower.

FIG. 8.



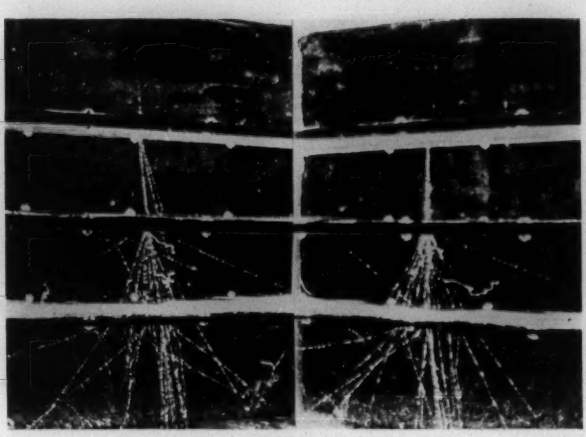
A graphic illustration of the exchange of energy from an electron to one or more photons in the upper plate. These photons are responsible for the continued progress of the shower below.

FIG. 9.



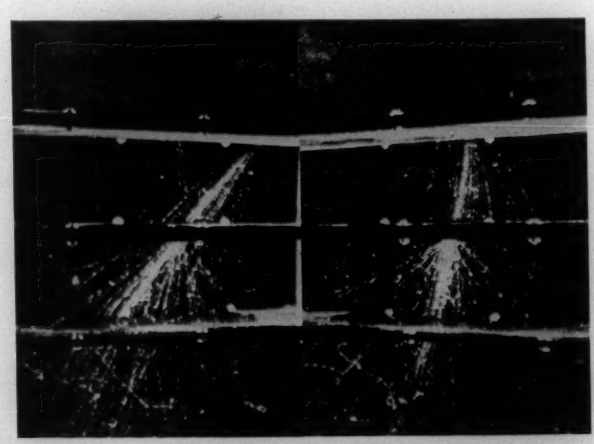
Another case of the development of a shower in successive stages.

FIG. 10.



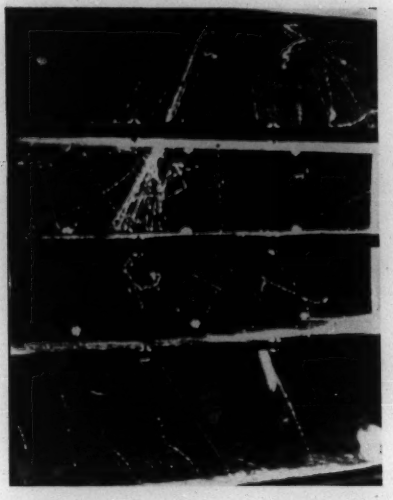
Development of a fairly large shower.

FIG. 11.



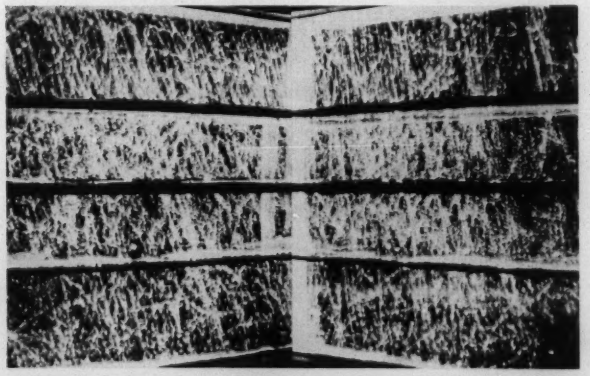
A case in which there is very strong multiplication in the upper and middle plates. The rapid absorption of wide angle shower particles is very evident.

FIG. 12.



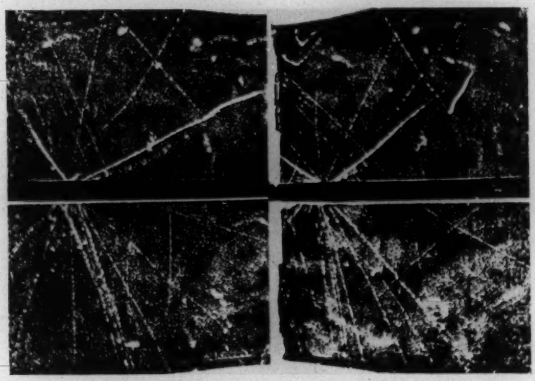
A shower which is nearly stopped. The energy of the particles has degraded to such an extent that multiplication is taking place less frequently than absorption.

FIG. 13.



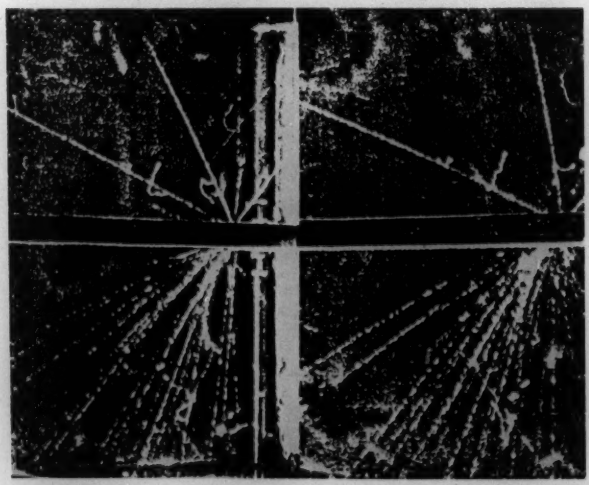
Occasionally very large showers are incident from above. It is a striking fact that many of these do not appear to diverge from any point in the roof or other nearby material. The shower development has evidently taken place in the air.

FIG. 14.



One of the rare showers in which dense as well as thin tracks can be seen. It is likely that the dense tracks are those of protons.

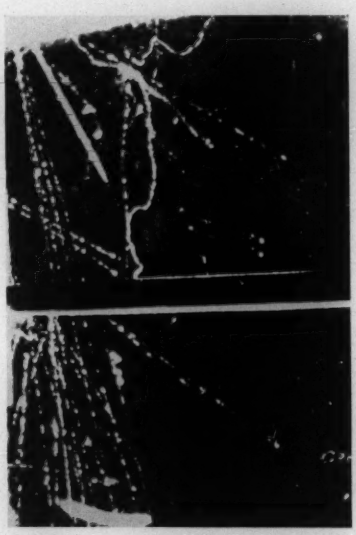
FIG. 15.



Another case in which some of the shower particles are heavy. The backward divergence of shower particles, although rare in the multiplicative phenomena, occurs in almost all cases when heavy particles are present.

The explanation of the apparent point origin of shower rays from a plate of moderate thickness can be found in the rapid absorption and small multiplicative power of the rays which diverge at wide angles. For this reason the only observable wide angle rays are those generated in the lower millimeter or two of the plate and since the apparent "center"

FIG. 16.

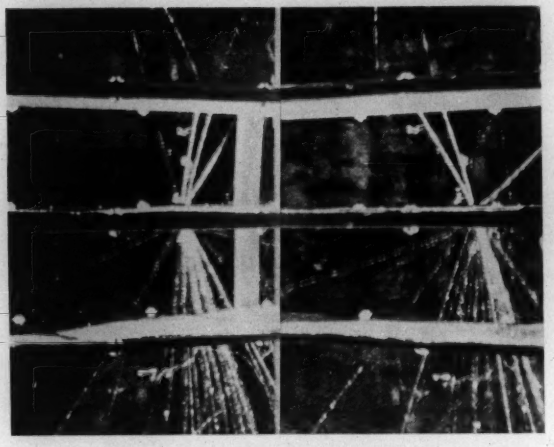


A shower from above has one heavy track and several thin ones. Some multiplication takes place in the 1.3 cm. plate, but the penetration and relatively small multiplication exhibited by the close group of four thinly ionizing particles is unusual.

of the shower is largely determined by these the impression is misleading. An inspection of the photos justifies this explanation.

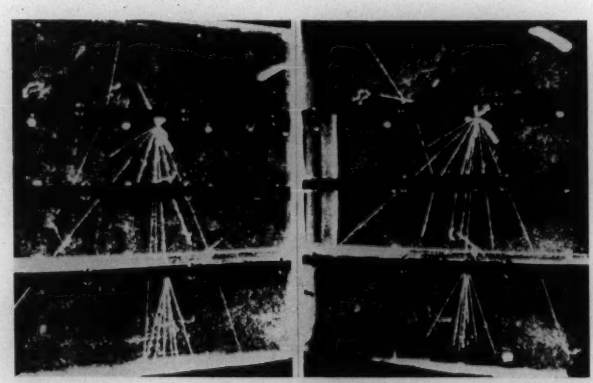
Fussell's data also show the presence of showers containing dense tracks. In all of his pictures, however, only five such cases were found. See Figs. 14–18. It is clear, therefore, that these play a relatively unimportant part in shower

FIG. 17.



Another shower with both thin and dense tracks.

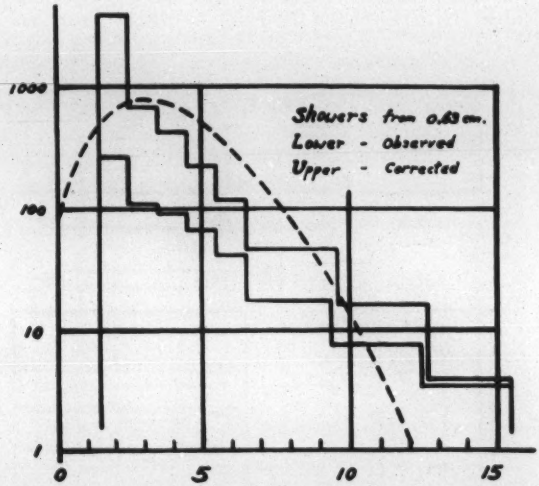
FIG. 18.



An unusual shower is produced in the thin lead plate which in this case is above. Three dense tracks of short range emerge from beneath the plate and another can be seen above it. Some multiplication takes place in the lower plate near the center but two *wide angle* thinly ionizing particles penetrate the two lower lead plates with no multiplication. This is a very unlikely event if these particles are electrons. The original photograph was taken under conditions which rendered good reproduction impossible. The thin tracks have been retouched for clarity.

phenomena from the point of view of intensity. (The relative importance of such showers may be greater at higher elevations.) For the sea level showers then, it no longer appears so arbitrary to relegate this type to some separate infrequent process.

FIG. 19.



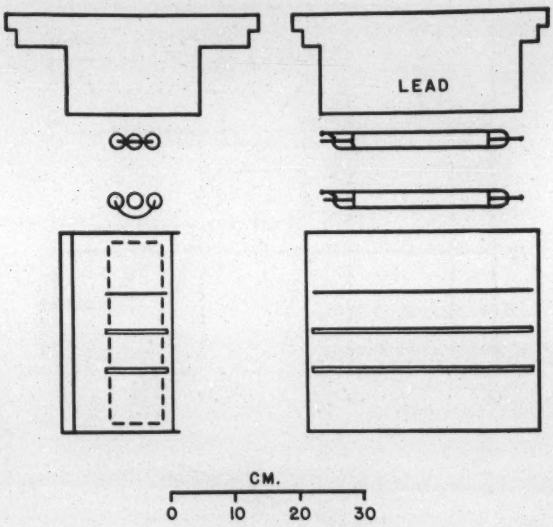
The distribution of shower sizes observed with the arrangement of Fig. 5. Only cases which develop from a single entity within the upper 6.3 mm. plate are included.

A plot of the distribution of shower sizes is shown in Fig. 19. This represents only cases which develop from a single entity within a 6.3 mm. plate. A second plot on the same figure gives the distribution corrected in an approximate fashion for counter selectivity. The correction is difficult to make and somewhat uncertain but the second plot is no doubt closer to the true distribution than the uncorrected data. The approximately exponential form of the distribution is in agreement with what might be expected on the basis of the statistics which Furry has shown must apply in multiplicative processes.[7]

[7] W. H. Furry, *Phys. Rev.*, **52**, 569 (1937).

If the usual showers observed at a thickness of lead in the neighborhood of the peak of the Rossi curve are to be regarded as properly described by the multiplicative theory, some other process must be assumed to account for the quite appreciable number of showers found under thick layers of material (10 cm. of lead and greater) for the absorption in such layers should be expected on the basis of the theory to reduce the

FIG. 20.



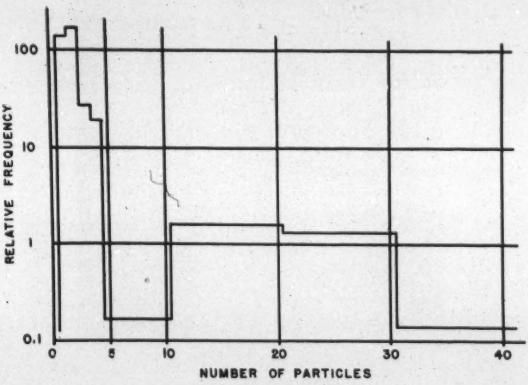
Arrangement of apparatus for the study of showers emerging from a 15 cm. lead block.

intensity to a small fraction of the initial value. At the time of his Harvard lecture Oppenheimer was of the opinion that the energy for such processes was transmitted by protons. Later, however, he pointed out that better correlation with cloud chamber data could be had by postulating the existence of particles of mass intermediate between the proton and electron.[4] This view, which at the time could not be regarded as definitely proved, is now generally accepted for reasons

which will be discussed later in this paper. Fussell has taken in the course of his investigation some 400 photographs of the showers which enter a cloud chamber from a plate of lead 15 cm. thick. The arrangement used is shown in Fig. 20.

The distribution of sizes of the showers entering the chamber for this arrangement is plotted in Fig. 21. The result is striking in showing an unexpected gap in the distribution for sizes between 5 and 10 rays. No reason for this is apparent unless it is assumed that the showers on the two sides of the minimum arise from different processes. The

FIG. 21.

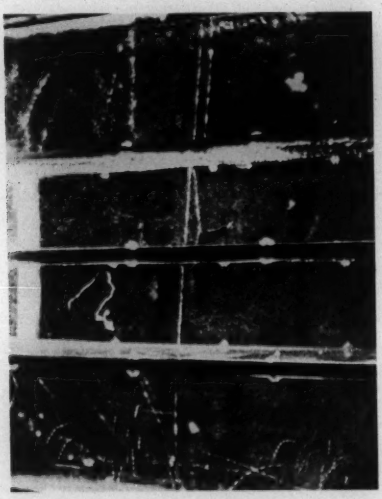


The frequency distribution of the sizes of showers entering the chamber from the thick lead block. All time coincident tracks in the upper section of the chamber are counted.

general features of the small showers are in agreement with the assumption that they are produced by the penetrating particles through the intermediary of extra-nuclear electrons ejected in close collisions. Two ray "showers" are predominant (Fig. 22) and multiplication is infrequent and seldom extensive indicating the relatively low energy of the knock on electrons. This is also shown by the strong absorption of all but one of the rays in many of the small showers. As suggested above it is possible that the larger showers from thick lead are due to some other process. The

appearance of some of these indicates the presence of several penetrating rays among the shower particles but this general impression obtained from inspection of the photographs may be erroneous and certainly requires further proof. Examples

FIG. 22.



The most usual type of event observed with the arrangement of Fig. 20.

of the larger showers from the thick lead plate are shown in Figs. 23, 24, and 25.

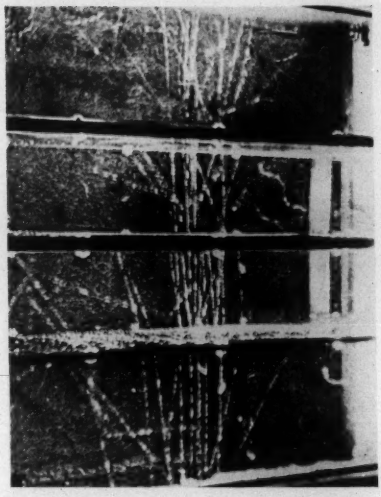
The Penetrating Particles.

The existence of penetrating ionizing particles was first suggested by the experiments of Bothe and Kohlhörster [8] and later proved by the counter experiments of Rossi.[9] More recent cloud chamber investigations have verified Rossi's conclusions that some 70 per cent. of the particles observed at

[8] Bothe and Kohlhörster, *Zeits. f. Physik*, **56**, 751 (1929).

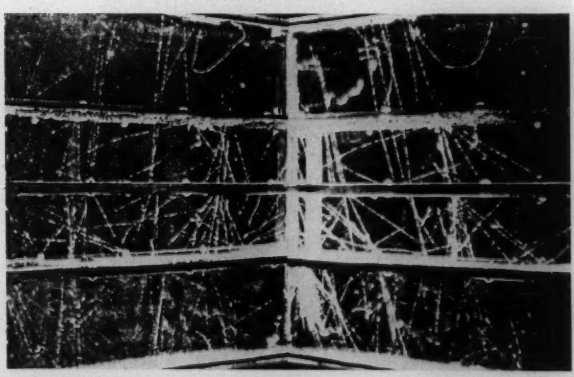
[9] B. Rossi, *Zeits. f. Physik*, **82**, 151 (1933).

FIG. 23.



A shower of several particles from the thick lead. The multiplication is somewhat less than would be expected for electrons.

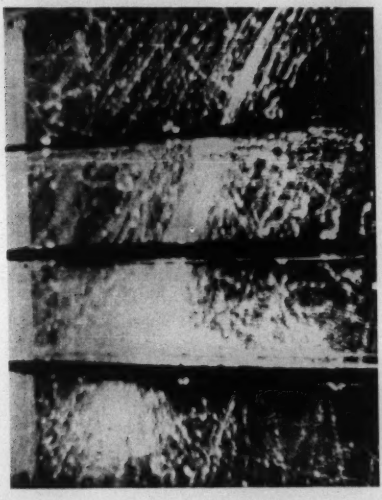
FIG. 24.



A shower in which some of the rays are from the lead block and others are ejected by radiation which apparently did not strike the block, e.g. see the intense disturbance in the lower left corner.

sea level are continuously ionizing, possess great power of penetration, and produce very few secondaries.[10] It has also been shown that the mass absorption law holds for this radiation. It is obvious that these characteristics with the exception of the continuous ionization are not those of electrons if we are to believe in the Bethe-Heitler radiation and pair formation theory. Carlson and Oppenheimer [4]

FIG. 25.



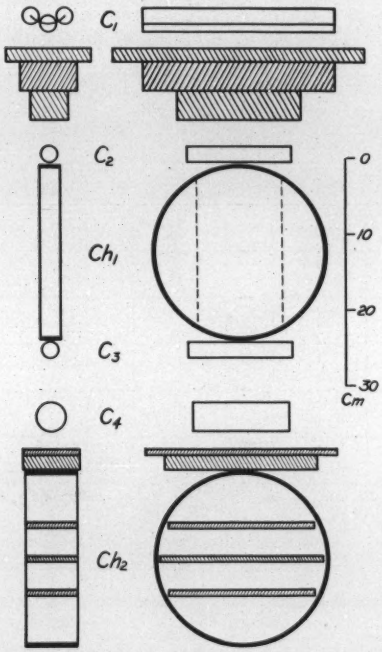
A shower from the lead block which shows intense multiplication in the chamber.

discussed this point in their paper on multiplicative showers and as mentioned above *first* proposed the existence of particles of intermediate mass. This proposal could not be accepted with any great feeling of confidence until it could be shown conclusively that the penetrating rays are not protons and that their characteristic penetrating power and low intensity of accompanying secondaries are maintained down

[10] Auger and Ehrenfest, *Comptes Rendus*, **199**, 1609 (1934); Street, Woodward, and Stevenson, *Phys. Rev.*, **47**, 801, 1935.

to the momentum range over which direct studies of these characteristics for shower electrons had verified the radiation theory.

FIG. 26.

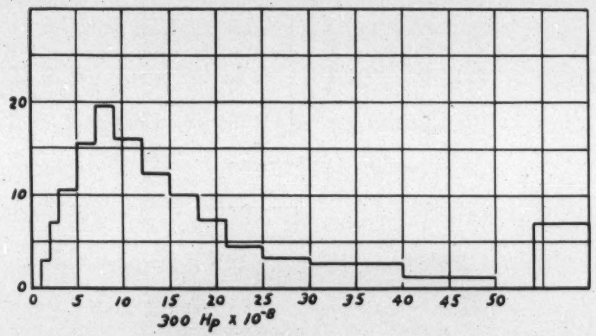


Apparatus for the study of the range, energy, and shower production of the penetrating particles. The upper cloud chamber is in a magnetic field of approximately 7,000 gauss. The cross hatched material is lead. C_1, C_2, C_3, and C_4 are counters which control the simultaneous expansion of the two cloud chambers.

In the summer of 1936 we were already engaged in an experiment to determine by a cloud chamber method the range energy relationship for the penetrating rays. To turn this experiment to the clarification of the points mentioned above was an obvious course. The apparatus for this investigation is shown in Fig. 26. The four counter telescope

including the 10 cm. lead filter below the top counter was designed to select particles of the penetrating group. The upper cloud chamber was used to measure the momentum of the rays selected by the counters and the lower cloud chamber to observe the corresponding penetration and secondary production. The results were clear in showing that the particles in question could not be protons. The possibility that they were electrons could equally well be eliminated if the shower electron energy loss measurements of Anderson and Neddermeyer up to 300 MEV were accepted as correct. (Our

FIG. 27.



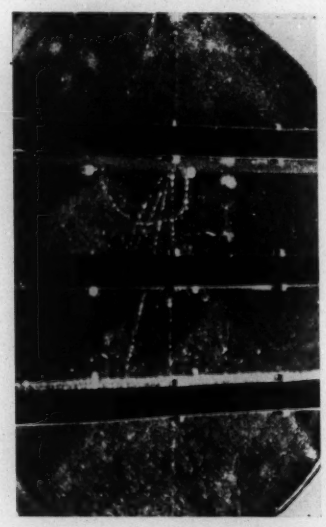
Momentum distribution of the penetrating particles selected by the counter arrangement of Fig. 26. A deflection measurement at $300H\rho = 10^8$ has a probable error of about 12 per cent. The block at the right has an area to correspond to the number of tracks with momenta beyond the limit of measurement.

confidence in these was of course intensified by the shower observations which Fussell was making during this same period.)

It is clearest to justify these statements by a specific illustrative example taken from a set 360 tracks with the momentum distribution shown in Fig. 27. A positive particle with $300H\rho = 197 \times 10^6$ exhibited a track of approximately electronic density in both upper and lower cloud chambers and passed through 6 cm. of lead with no production of secondaries. The properties of a proton of this momentum are as follows: energy 20 MEV, range approximately .15 cm.

of lead, track density about 13 times that for high speed electrons. It is obvious, therefore, that the example in question was not a proton. If we use the method of calculation recently outlined by Brode [11] it can be shown that the upper limit for the mass of this particle is about one tenth that

FIG. 28.

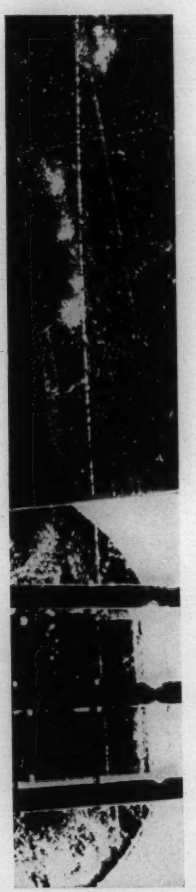


The largest shower (five emergent particles) produced by penetrating particles in some 1,000 traversals of 1 cm of lead. The energy of the incident particle as determined from the track in the upper cloud chamber was greater than 5×10^9 e.v. Shower phenomena are rare. Not counting single secondaries only four showers were produced in 1,000 traversals by penetrating particles distributed over the entire momentum range.

of the proton. It is not significant to state the result of this calculation more precisely because of the uncertainty of the absolute values of the ionization energy loss of fast protons in lead upon which the deduction is based. The $H\rho$ value for this track is well within the range for which Anderson and Neddermeyer reported agreement between theory and experi-

[11] R. Brode, *Phys. Rev.*, **53**, 773 (1938).

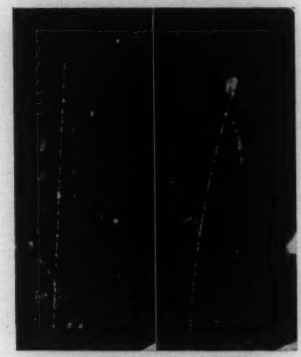
FIG. 29.



A composite photo showing the appearance of a typical track in upper and lower cloud chambers.

ment for the radiative energy losses of shower electrons. It can be shown from the magnitude and fluctuations of these losses [12, 7] that the probability for an electron with this momentum to have a range greater than 6 cm. of lead is less than .00001. Of the 9 tracks 2 positive and 7 negative observed in the range $300H\rho = 100 - 300 \times 10^6$ three had ranges greater than 6 cm. lead and thus the possibility of interpreting the group as electrons is practically eliminated since the chance for such an observation is less than one in

FIG. 30.



A composite showing the upper chamber photo of the lowest energy barytron observed ($300H\rho = 118 \times 10^6$) and of another not measurably deflected.

10^{14}. Of the 21 tracks in the range $300 - 500 \times 10^6$ (13 positive and 8 negative) there were nine with ranges greater than 6 cm. lead. A fraction less than .00005 would be expected to show this penetration on the electron theory.

This summarizes the evidence on which we based our first report of the existence of a new type of particle.[13] Recent experiments [14, 15] of a more direct nature have justified this

[12] Heitler, W., "Quantum Theory of Radiation," p. 226. Oxford Press, 1936.

[13] Street and Stevenson, Washington Meeting of the American Phys. Soc. April 1937, *Phys. Rev.*, **51**, 1005 (1937).

[14] Street and Stevenson, *Phys. Rev.*, **52**, 1003 (1937). See also reference 11.

[15] Williams and Pickup, *Nature*, **141**, 684 (1938).

conclusion and have shown that the mass of the new particle (barytron?), if unique, is probably in the range 150 to 250 times the rest mass of the electron.

The number of tracks is too few to provide satisfactory statistical data on the range energy relationship for barytrons but it is clear that there is considerable straggling. Many of the particles with $300H\rho > 400 \times 10^6$ are stopped within 3 cm. of lead. This may be taken as evidence for the existence of strongly fluctuating energy losses as well as the usual ionization losses. The fact that the momentum distribution curve falls off rather sharply on the low side of the maximum which is at about 700 MEV can be explained by assuming that some mechanism of energy loss in rather large steps sets in strongly at low energies.

The average energy loss over a wide range can be obtained by comparing the energy distribution curve, which can be determined from the momentum distribution by assuming a definite mass for the barytron of say $200m_e$, with counter absorption data in the manner first described by Street, Woodward and Stevenson,[10] and later used by Blackett.[16] The measurements under discussion here are very suitable for this comparison since they were obtained under conditions similar to those for the counter measurements, and the use of a filter eliminates the necessity for corrections for soft rays. The median of the energy distribution is at about 1,350 MEV. Counter absorption measurements show that the intensity with a 90 cm. lead absorber is half that with 10 cm. (the thickness of the lead filter used in taking the cloud chamber data). The average energy loss over this region is therefore 1,350/80 = 17 MEV/cm. lead. Since this result is not markedly greater than the expected ionization losses it is to be concluded that the fluctuating losses which are responsible for the straggling mentioned above cannot be large for energies greater than some 400–500 MEV.

[16] P. M. S. Blackett, *Proc. Roy. Soc.*, **159A**, 19 (1937).

THE ADAPTATION OF A SMALL CLOUD CHAMBER TO THE STUDY OF ELECTRON SHOWERS.

BY

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Bartol Research Foundation of The Franklin Institute, Swarthmore, Pa.

BARTOL RESEARCH FOUNDATION
Communication No. 97.

Smallness and portability in a cloud chamber are synonymous with certain geometrical limitations from which the cosmic-ray investigator must escape if this type of instrument is to be widely used. Unfortunately, it is only the rare investigator who can command the facilities necessary for experiments involving the transportation of large chambers and massive control apparatus from one place to another. This fact, and the experience and skill necessary to operate these large chambers, seriously limit the use of this very valuable instrument. The spatial extension of most cosmic-ray phenomena is rapidly leading to larger rather than smaller units. Thus, while the Geiger counter and ionization chamber grow more and more accessible to the average investigator, the cloud chamber becomes, if anything, less so.

We are reporting here a small chamber built primarily as an instrumental experiment. In spite of the fact that geometrical limitations are drastic, the instrument has been adapted to a study of electron showers. In order to do this to the best advantage, we have departed in a number of respects from conventional procedure. The procedures adopted have, on the whole, justified themselves, and are suggestive of many useful applications. The apparatus was entirely automatic. From 12 to 15 pictures were taken an hour, and the only attention required involved changing the film in the camera twice a day. In spite of the fact that the chamber contained a relatively large partition, turbulence was not serious and the expansion ratio not critical. In one instance, other work necessitated that the chamber lie idle for a period of three months. At the end of this time it gave, with only a slight adjustment, excellent beta-ray tracks.

The limitation of the instrument is a failure to resolve or separate rays lying close together. This is a consequence of the very short distance the rays travel in the chamber. The obvious solution is an increase in the depth both above and below the lead partition. This is to be recommended, and a great improvement can be achieved without approaching anything which might be thought of as a large chamber.

For most cosmic-ray studies a cloud chamber is controlled by a counter system, that is, the chamber is expanded upon the simultaneous discharge of two or more Geiger counters placed in the vicinity of the apparatus. The disposition of these counters depends upon the experiment itself. When the investigator wishes merely to record the passage of a single ray, two counters, one above and one below, provide the minimum in control equipment. When a shower is to be detected, more counters must discharge simultaneously as an indication of greater multiplicity. It is no criticism of those using cloud chambers for shower studies to state that in most cases their counter systems have been very inefficient detectors of showers. These studies have mostly been concerned with structure, and there was no reason to be disturbed by the fact that the "control," because of its inefficiency, was biased in favor of the large and complicated burst. This inefficiency can be serious, however, where the frequency of occurrence of a phenomenon in a cloud chamber is to be taken as indicative of its frequency of occurrence in nature. For the small chamber containing a shower producing specimen, it is a nuisance on all counts. A great deal of time can be consumed in getting a few pictures, the vast majority of which have nothing to do with phenomena arising in the specimen itself. This is particularly true where the pictures are taken inside a building or in the presence of any sizable amount of shower producing material. For this reason, the first concern in adapting the small chamber for shower work is to employ a "control" which confines the pictures taken, or a great percentage of them at least, to showers actually arising inside the chamber. It is then equally necessary to see that the "control" is efficient in detecting these none-too-frequent showers.

These two ends were achieved in the chamber shown in Fig. 1 by employing a shower arrangement consisting of three small counters placed horizontally directly below the specimen inside the cloud chamber itself, and a continuously sensitive surface of long narrow counters placed under the chamber. A picture was taken when at least one counter under the specimen discharged simultaneously with any two counters in the exterior surface. The counters placed in the chamber render the arrangement selective—the great number and arrangement of the exterior counters make it efficient.

FIG. 1.

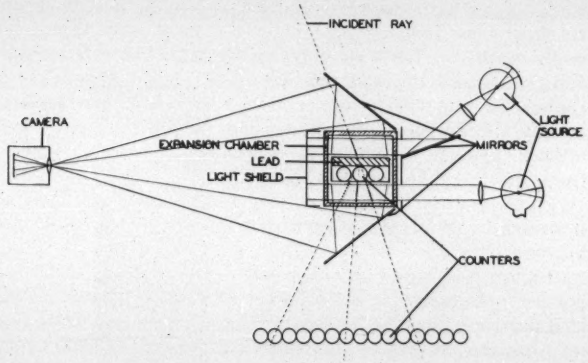


Figure 1 is a schematic diagram showing the end view of the chamber, and the general arrangement of the apparatus. In order not to obscure the essential features, we have not indicated that portion of the unit which lies behind the chamber proper. It will be seen from this figure that, by means of two mirrors, pictures are made simultaneously of the top and bottom of the chamber. Further examination will indicate that pictures of the shower tracks were taken as they would be seen by an observer facing the oncoming rays. Of course, in the top half the ray through the chamber is receding from the observer. The reader may suspect at first glance that this rather bizarre procedure was prompted

entirely by experimental curiosity. However, further consideration will show that this can be, indeed, a very instructive way to take such a picture. The members of a shower diverge from the lead and appear radiating from a point, presenting an appearance not unlike that given by the petals of a flower. In this position, the tracks are relatively easy to count and it is not necessary to resort to the stereoscopic principle in order to assign the position of each ray in space. Furthermore, this assignment involves only the taking of two simple measurements on the film—the length of the track, and the angle which it makes with one edge of the chamber. Because many of the shower particles are making relatively small angles with the vertical, quite a few of the tracks will be short, and reduced to a point for those rays which are really vertical. These short tracks are quite heavy in appearance, as would be expected. A track in the chamber one centimeter long will, from a position where its length seems to be, say a millimeter, appear as a heavy particle track. This follows from the fact that the total amount of light received from the track is approximately the same in all positions. (We are here, of course, confining our attention entirely to positions in which the observation is at right angles to the incident light.)

Figure 2 is a picture taken with the chamber. The top portion presents what the observer sees looking down on the lead partition, and the bottom portion what he sees in looking up from the bottom of the chamber. This is a photograph of a five-ray shower coming from the upper part of the lead and produced by an electron shown entering the chamber from above. This picture brings out a number of the things previously mentioned. It will be observed that four of the shower tracks are quite short, and heavy—these rays were making a small angle with the vertical. The fifth track is considerably longer and, likewise, correspondingly lighter. This ray described a much larger angle with the vertical. The petal-like appearance is apparent.

The limitation of this photographic procedure is also obvious from this picture. The length of a track is proportional to the depth of the chamber and the assignment of the angles depends upon this length. Therefore, the extreme

shallowness of our instrument makes this situation about as bad as it can be. Certainly the chamber should be deepened for quantitative work and this limitation reduced as much as possible. By arranging the counter system properly, we can increase the average path length of a ray in the chamber without deepening the chamber. This procedure can be employed, of course, only in investigations where it is possible to confine the phenomena to rays describing a large angle with the vertical. In any case, this limitation can be reduced so easily that it provides us with no serious criticism of the procedure. A little thought will suggest a number of experiments where it is definitely easier and more instructive to take the pictures in this manner.

FIG. 2.

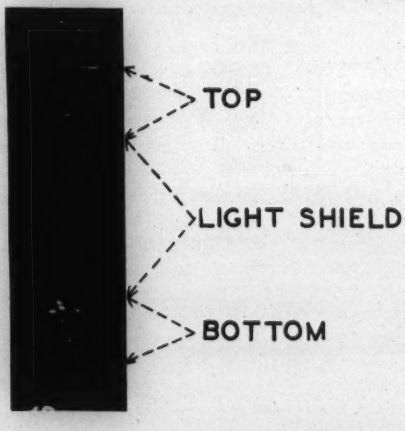
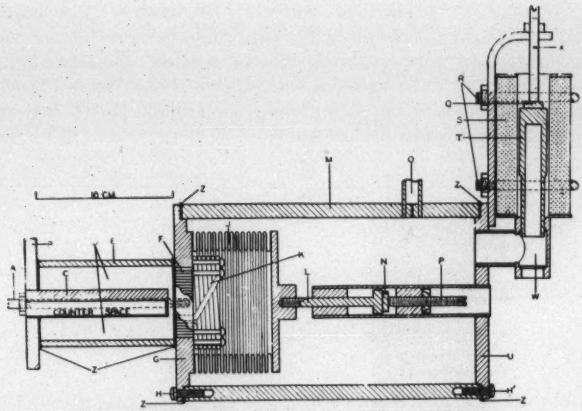


Figure 3 is a detailed, but somewhat simplified, drawing of the chamber. Most of the mechanical features will be more or less obvious from the diagram and its associated caption. A few matters will merit some additional description.

The glass chamber was constructed from four plates of polished pyrex. These plates were fastened together (with

wire around the ends) to form an open glass box. This box was placed on a small revolving plate inside an electric oven. The oven was then raised to a temperature just under the melting point of pyrex, and the center portion of the edges of the box sealed together using a small oxygen flame intro-

FIG. 3.



A—Bolts which hold pyrex glass chamber *E* in place.
B—Chamber end plate supporting lead specimen *c* and counters.
D—Active volumes of chamber.
F—Nickel grid.
G–U—End plates of cylindrical steel tank *M*.
H–H'—Bolts which fasten end plates—there are twelve of these on each end.
J—Sylphon bellows.
K—Nick to introduce alcohol.
L—Sliding guide.
N—Leather pad to cushion shock of expansion.
O—Compressed air (pressure 10 lbs.) inlet, with small leak.
P—Expansion ratio adjusting screw.
Q—Rubber pad.
R—U bolts which support release valve solenoid *S*.
T—Sliding iron case of expansion release valve.
W—Expansion release valve.
X—Expansion valve adjustment.
Z—Rubber gaskets.

duced through a hole in the side of the oven. The unit was then allowed to cool slowly, the wire removed, the chamber returned to the oven, and the remaining portion of the edges sealed together. This whole process was performed so expertly by our glassblower, Mr. Nester, that the optical

surfaces of the box were undisturbed. The ends of this box were then ground flat and in such a way that the end planes were at right angles to the edges. In Fig. 3 we see this chamber clamped between the end plate which carries the partition and its counters, and the chamber which controls the expansion.

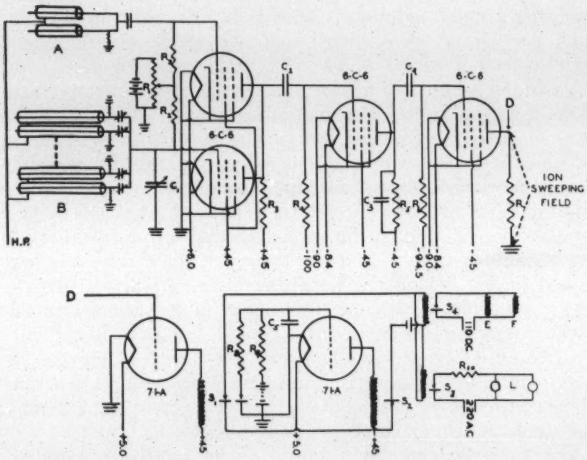
The relative freedom from turbulence was largely due to the introduction of a honeycomb grid between the chamber and the copper sylphon. This grid was built up of .005 inch corrugated sheet-nickel and the whole bundle bound together by a nickel band. The grid, when finished, was 1.3 cm. deep and had approximately the same linear dimensions as the end of the observation chamber. It is mentioned here in particular, for we feel that it is superior in reducing turbulence to the wire gauze usually used for this purpose. n-propyl alcohol vapor was introduced into the chamber, employing a procedure used by Dr. G. L. Locher of this laboratory. A long cotton wick is wound into a spiral inside the expanding unit, led out to a small sylphon reservoir (not shown in Fig. 3) on the outside. By compressing this exterior reservoir, the alcohol is brought into contact with the wick or removed, as desired.

The chamber was washed and filled with argon gas at approximately atmospheric pressure. This gas, when employed with isopropyl alcohol vapor, gives beta-ray and cosmic-ray tracks for an expansion ratio of about 1.1.

Figure 4 is a circuit diagram of the control apparatus. The shower unit utilizes a principle which has been employed frequently by one of us (W. E. R.) in other connections. The key element (B) in this unit is a layer of fifteen long, narrow, thin-walled counters, coupled through small adjustable condensers to the grid of one adding tube in a coincidence circuit. By varying these condensers, the voltage pulses from this array of counters may be equalized, and the size of the voltage swing on the grid of the adding tube made to depend only upon circuit constants and the *number* of counters which have discharged simultaneously. By varying the condenser C_1, any number of these simultaneous discharges may be assigned as a minimum requirement for the operation of the tube concerned. The other adding tube receives its pulses from

the small counters A within the chamber. We thus add coincidences between these small counters and the large tray. When C_1 has such a value that the discharge of *any two* counters in the tray is sufficient, with a simultaneous discharge of a small counter, to operate the chamber, we have a situation in which the efficiency for shower detection is a

FIG. 4.



R_1—400 ohms.
R_2—1 megohm.
R_3—0.1 megohm.
R_4—0.5 megohm.
R_5—10.0 megohms.
R_6—10.0 megohms.
R_7—0.2 megohm.
R_8—0.5 megohm.
R_9—10.0 megohms.
R_{10}—30 ohms approximately

C_1—200 $\mu\mu$f approximately.
C_2—100 $\mu\mu$f.
C_3—0.1 μf.
C_4—1 μf.
C_5—1 μf.
S_1, S_2, S_3—E-5 relays.
L—110 volt single filament lamps.
E—Expansion solenoid.
F—Camera release.

maximum. In order that this adding circuit may work satisfactorily, it is necessary to evoke all the precautions ordinarily taken to achieve good adding and a few peculiar to this arrangement. Space does not permit a really adequate discussion of all these matters. However, a few comments here will be sufficient for the particular applications which are concerned in cloud chamber control.

The resistance in the plate circuit, and the plate and screen grid voltages, are so chosen that for values of the control grid potential more positive than, say, V_0 large changes of potential of the grid produce little change in the plate potential. At V_0 the plate potential starts to change rapidly and assumes the value of the applied voltage for only a small decrease in the bias. The resistance and the voltages mentioned may be adjusted in different ways to achieve this end, and as a rule other restrictions imposed by the remainder of the circuit are allowed to determine the best choice of constants. Generally speaking, the plate resistance should be made as large as possible consistent with the requirement that the response of the plate circuit is fast compared to the recovery time of the control grids. For example, it would be obviously foolish to increase this resistance until the plate potential requires 10^{-5} of a second to come to equilibrium and expect the circuit to operate when the grid recovers from a counter pulse in 10^{-6} sec. It is good practice to insist that the recovery time of the grid be at least ten times as long as the response time of the plate. By increasing the screen grid potential, we make the cut-off more remote, and increase the working range of the tube. The plate potential is to some extent determined by the size of the pulse one desires to transmit to the remainder of the circuit. The lower this voltage the sharper the cut-off, but the smaller the pulse.

For this type of control the equalization of counter pulses is not a very exacting process. It may, therefore, be accomplished using the circuit itself. The question of resolution is not involved and for this adjustment the cut-off characteristics of the adding tubes may be rendered very much more pronounced. The procedure follows:

Remove the adding tube associated with the small counters in the chamber. Increase the time constant of the remaining grid to at least 10^{-3} seconds, and push up the plate resistance to 10^6 ohms or more. Now remove the plate resistance of the next tube and insert a pair of ear phones. In addition, temporarily increase the grid resistance to 10^7 ohms. We now have a remote and fairly sharp cut-off. Assign the counter voltage at which you wish to work (one hundred volts or more above the starting potential). Increase C until its

value is, say, 200 cm. Varying the small coupling condensers on the separate counters will now not seriously change the total capacity of the grid circuit. Grounding all the counter cylinders except one, apply the counter voltage to this cylinder. Set the bias on the first vacuum tube two volts or so more positive than the cut-off point and adjust the coupling condenser of this counter until pulses just come through the ear phones. Repeat the process with each counter. The operation is rapid, and when the adjustment is made it holds for all resolving times not shorter than the break-down time of the counters.

Now connect all the counters in the tray to the high potential, restore the original resistances (leaving the ear phones in) and set the bias on the grid of the first tube at a value such that single counter pulses do not come through. Knowing as we do the size of the individual pulses on the grid, we may assign a bias such that no single counter discharge can get through, but that two such simultaneous discharges are sufficient. The ear phones may now be removed, the 10^7 ohm resistance replaced, and this part of the circuit is ready to operate. It must be borne in mind that this adjustment holds strictly for only one counter potential. While there is nothing very critical about this potential, it should be maintained at approximately the assigned value.

Now when a shower coincidence occurs, the positive pulse applied to the grid of the third tube is effective in killing off the fourth tube. This immediately removes the sweeping field on the cloud chamber and actuates the relays which control expansion solenoid, light source, and camera release. The potential of the point D, because of the delay in the plate of the third tube, remains zero for something under a second. The positive surge on the first 71-A closes a relay and two associated contact points. The first at once, in a manner obvious from the diagram, initiates the expansion, turns on the light (single filament bulbs flashed at 180 volts) and opens the camera shutter. In the meantime we see that the grid of the second 71-A is becoming more positive as a consequence of the closing of the second contact and soon opens the relay S_2, releasing all the controls. This relay remains open for several seconds and by the time it closes again the relay S_1 is

open. It will be seen that the circuit is now restored to its original state and ready for the next coincidence. Partial expansions were found unnecessary with this chamber.

The sweeping field used here (approximately 90 volts) is relatively high for such a small chamber. It is applied between the central metal partition and aquadag strips along the inside edges of the chamber. The contact with the aquadag is made through thin aluminum foil inserted between the rubber gasket and the glass chamber. This potential is removed from the strips in 10^{-4} seconds or less.

In conclusion, the authors wish to express their appreciation to Dr. W. F. G. Swann for his interest, complete coöperation, and help. Also they desire to thank all others at the Laboratory who offered suggestions and criticisms.

Quanta Phenomena.—A. A. MERRILL. It happens that recently there has been much confusion concerning the philosophical meaning of what are called "quanta phenomena." If this matter applied only to the work of specialists I would not mention it here, but in fact, a similar confusion exists between laymen and causes many misunderstandings. Fundamentally it is due to the fact that few people realize that the word "chance" has two different meanings and we continually jump from one meaning to the other without realizing that we jump. The two meanings are (1) "Chance" means that there is no "causal" relation between an event and the past, and (2) "Chance" means that the present event could not be predicted by humans because of limitations in our ability to obtain knowledge. Now it is because of the existence of these two meanings for the word "chance" that there has been so much squabbling over the supposed antagonism between "free-will" and "determinism." If you define "free-will" as an event not related causally with the past, believe me there is no evidence that "free-will" exists; but if you define "free-will" as an event that can not be correctly predicted by humans, then as it happens, there is evidence of the existence of a sort of "free-will" even in the inanimate world, namely "quanta phenomena." Just remember that no finite being, not even Eddington, can prove a NON-existence, which you must prove, if you posit "non-causality."

Quanta phenomena seem to me to show that there are dynamic events which are "privileged" in the sense that they exist in a temporarily closed system and from their very nature make it impossible for humans to predict them individually; the best we can do is to make a statistical prediction, giving a figure for probability.

Use of Rayon to Increase More Slowly.—Some further expansion in the use of rayon in the next few years is to be expected but no such tremendous relative gains as those of the past are likely. This view was expressed in a report by a Department of Agriculture committee appointed by Secretary Wallace to study developments in rayon and other synthetic fibers. Considering its present properties, and its price relative to those of competing fibers, rayon is approaching a limit of expansion in those fields for which it is suitable, the committee said.

R. H. O.

THE THEORY OF NUCLEAR STRUCTURE.*

BY

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It seems appropriate to open this meeting with an attempt at a broad survey of what we think we know about nuclear structure, and of what are the most serious gaps in our knowledge. We may start by listing what are the main points in the theoretical views that are held today:[1]

(1) We suppose that the nucleus which has a charge Z and mass number A consists of Z protons and $(A-Z)$ neutrons, the associated neutral atom containing Z electrons in its extra-nuclear structure.

(2) We suppose that these particles obey the principles of quantum mechanics as set forth, for example, in Dirac's book. Also, we accept the relativistic principle of equivalence of mass and energy.

(3) We suppose that electrons, protons, and neutrons obey Fermi-Dirac statistics, i.e., that all wave functions involving more than one of any of these kinds of particles is anti-symmetric in the coördinates of like particles. Also, that these particles each have a spin angular momentum of $\frac{1}{2}\hbar$.

(4) We suppose further that charged particles interact according to the Coulomb law, and interact with the electromagnetic field in the sense implied by Maxwell's equations, both through their charges and through their magnetic moments.

(5) We suppose that protons and protons, and protons and neutrons interact with each other by means of additional specifically nuclear interactions which are negligible at greater distances than 10^{-12} cm. and at distances of the order 10^{-13} cm. are much greater than the Coulomb interactions.

* Based upon a paper presented at the University of Chicago Symposium on Nuclear Physics, June, 1938.

[1] The outstanding general summary of the literature up to two years ago is Bethe and Bacher, *Rev. Mod. Phys.*, **8**, 82 (1936).

(6) We suppose that a proton can be converted into a neutron plus a positron or a neutron into a proton plus an electron by laws which are very imperfectly understood, and which apparently involve violations of the conservation laws of energy, momentum, spin, and statistics. We suppose, also, that it is possible to relate the phenomenologically introduced magnetic moments, and the specifically nuclear interactions to relations of the heavy particles to an electron-neutrino field or to some other type of quantized wave field suited to the purpose.

The principles have been listed in an order of decreasing certainty or definiteness of our knowledge about them. While the subject seems to fall quite naturally into the parts as listed, we must be prepared from past experience in other branches of theoretical physics to have the resolution of later difficulties come by radical revision of the parts of the subject which are currently taken for granted.[2]

Let us now turn to some of the important results and problems which are related to the principles just enumerated.

(1) This view of proton-neutron composition instead of the previously held hypothesis of proton-electron composition was introduced speculatively by Harkins long before the discovery of the neutron, and was developed by Heisenberg as a quantum mechanical theory soon after the discovery of the neutron. It avoids difficulties characteristic of the proton-electron hypothesis arising from spin and statistics of nuclei and also connected with the fact that the nucleus is too small to hold electrons without introduction of extraordinary forces.

(2) As to the use of quantum mechanics, this is done simply because there is no reason not to extend its use from the well-tested extra-nuclear domain into nuclear problems. The principle of equivalence of mass and energy has received abundant and exact confirmation on a large number of nuclear reactions, especially with mass numbers below 20 where the mass measurements are quite exact.

(3) The validity of F. D. statistics for electrons underlies the whole theory of atomic spectra, of chemical valence, and of metals, and so is established beyond doubt by the many successes of these theories.

[2] Heisenberg, *Ann. der Phys.*, **32**, 20 (1938).

For protons we have as to spin and statistics the direct evidence of the alternating intensities in hydrogen molecular bands, and as to spin the additional evidence of the hyperfine structure of atomic hydrogen as revealed in the atomic beam experiments of Rabi, Kellogg, and Zacharias, using the Breit-Rabi method.[3]

For neutrons, however, it is well to emphasize that the evidence is less direct. The customary argument runs as follows: Assuming neutrons to obey F. D. statistics and to have a half-integral spin, then on the proton-neutron composition hypothesis a composite nucleus will have

Einstein-Bose statistics and integral spin for A even,

Fermi-Dirac statistics and half-integral spin for A odd.

Let us emphasize that this work does not show that the neutron spin is $\frac{1}{2}$, but only that it is half-integral. The usual assumption that it is $\frac{1}{2}$ has only the status of being the simplest possibility that is in accord with the data.

(4) The general validity of the Coulomb Law down to nuclear dimensions is shown for proton-electron interaction by the success of theories of extra-nuclear structure. Similarly for proton-proton interaction by the experiments on angular scattering of protons, deuterons, and alpha-particles at energies sufficiently low that the specifically nuclear forces are inoperative. This is also indicated by the success of the barrier leakage theory for alpha-particle disintegration.

The general validity of the Maxwell equation method of calculating interactions with the electromagnetic field is fairly well indicated by the success of calculations of effective cross sections for dissociation of the deuteron by gamma rays and the converse effect of radiative capture of neutrons by protons. The same is indicated by the general success of calculations on internal conversion of gamma rays.

Interactions with the electromagnetic field are also satisfactorily calculated in the underlying theory of the atomic beam experiments of Rabi and his associates and also in the molecular beam experiments of Stern's laboratory.[4] Out of this work has come the surprising result that the magnetic moment of the proton is 2.5 (Stern, et al.) or 2.85 (Rabi, et al.)

[3] Rabi, Kellogg, and Zacharias, *Phys. Rev.*, **45**, 769 (1934); **50**, 472 (1936).

[4] Estermann, Simpson and Stern, *Phys. Rev.*, **52**, 535 (1937).

times $\frac{eh}{2Mc}$ where M is the proton mass, i.e., about two and one-half times "what it ought to be"! The sign of the proton's magnetic moment is positive, i.e., related to the angular momentum as one would expect from the simple picture of the magnetic moment's being produced by rotating charge.

The analogous experiments for the deuteron give a magnetic moment of +0.8 in the same unit.

From evidence on proton-neutron scattering, we conclude that the normal state of the deuteron corresponds to zero orbital angular momentum, in which case the spins are parallel if the neutron spin is $\frac{1}{2}$ giving -2 for the magnetic moment of the neutron. If the neutron spin is $\frac{3}{2}$ then the spins are antiparallel giving + 3.6 for the neutron magnetic moment. That the magnetic moment of the neutron is antiparallel to the angular momentum is definitely shown by the recent experiments in Columbia and in Copenhagen, on the precession of neutrons in a magnetic field, so the fact of neutron spin of $\frac{1}{2}$ is now definitely established.[5]

(5) The information we have about the specifically nuclear forces is of two types, sharply distinguished by the accuracy with which the associated mathematical problems can be handled. The first type is that which is afforded by study of the two-body problems.

For proton-neutron interaction we have as essential data:

(*a*) The binding energy of the deuteron
$$8.97 + 8.13 - 14.73 = 2.37 \text{ millimass units.}$$
(*b*) The experimental fact of the isotropic angular distribution of scattering of neutrons by protons for neutrons up to about 10 mmu neutron energy.
(*c*) The variation with energy of the total effective cross-section of scattering of neutrons by protons, varying from $1 \cdot 10^{-24}$ cm.^{2} for energies of about 10 mmu up to a cross-section of about $30 \cdot 10^{-24}$ for neutrons of thermal energy.

[5] Powers, Carroll, Beyer, and Dunning, *Phys. Rev.*, **52**, 38 (1937); Frisch, von Halban, and Koch, *Phys. Rev.*, **53**, 719 (1938).

(*d*) The results on the scattering of slow neutrons by ortho and para hydrogen obtained by Stern, et al., and by Dunning, et al., and interpreted in accordance with the theoretical ideas of Schwinger and Teller.[6]

Before considering what can be learned from these experiments, let us first review briefly the formal possibilities for interaction laws which present themselves most simply. In classical mechanics the only possibility was that of a simple potential energy described by a general potential energy function $V(r)$. Quantum mechanics introduces us to wider possibilities in the way of exchange and spin dependent forces.

The wave equation for a two-body problem for two particles having position coordinates $\mathbf{r}_1$ and $\mathbf{r}_2$ and spin coördinates σ_1 and σ_2 will involve the kinetic energy terms

$$\frac{\mathbf{p}_1^2}{2M_1} + \frac{\mathbf{p}_2^2}{2M_2},$$

where M_1 and M_2 are the masses of the two particles. The wave function will be $\psi(\mathbf{r}_1, \sigma_1; \mathbf{r}_2, \sigma_2)$ dependent on spin and position of the two particles. Formally we may introduce a set of exchange operators $1, H, M, B$, defined by the equations:

$$\begin{aligned} 1\psi(\mathbf{r}_1, \sigma_1; \mathbf{r}_2\sigma_2) &= \psi(\mathbf{r}_1, \sigma_1; \mathbf{r}_2, \sigma_2), \\ H\psi(\mathbf{r}_1, \sigma_1; \mathbf{r}_2, \sigma_2) &= \psi(\mathbf{r}_2, \sigma_2; \mathbf{r}_1, \sigma_1), \\ M\psi(\mathbf{r}_1, \sigma_1; \mathbf{r}_2, \sigma_2) &= \psi(\mathbf{r}_2, \sigma_1; \mathbf{r}_1, \sigma_2), \\ B\psi(\mathbf{r}_1, \sigma_1; \mathbf{r}_2, \sigma_2) &= \psi(\mathbf{r}_1, \sigma_2; \mathbf{r}_2, \sigma_1) \end{aligned}$$

and may then introduce a more general interaction law

$$V(r) = V_1(r) + V_H(r)H + V_M(r)M + V_B(r)B,$$

where the four $V(r)$ functions are arbitrary and independent. Introducing coördinates of the center of mass and relative coördinates

$$\mathbf{R} = \frac{M_1\mathbf{r}_1 + M_2\mathbf{r}_2}{M_1 + M_2}, \qquad \mathbf{r} = \mathbf{r}_2 - \mathbf{r}_1$$

[6] Schwinger and Teller, *Phys. Rev.*, **51**, 775 (1937); Halpern, Estermann, Simpson, and Stern, *Phys. Rev.*, **52**, 142 (1937); Dunning, Manley, Hoge, and Brickwedde, *Phys. Rev.*, **52**, 1076 (1937).

in the usual way, the wave equation then becomes

$$\left[\frac{\mathbf{P}^2}{2(M_1+M_2)}+\frac{\mathbf{p}^2}{2M}+V(r)\right]\psi = W\psi,$$

in which $M = M_1M_2/(M_1+M_2)$, the usual reduced mass.

This formalism makes sense only if the particles are of the same mass, for otherwise, we are unable to separate the motion of the center of mass from the internal motion, and also if the particles have the same spin in order that the field of values of the two spin coördinates shall be the same. It is customary to neglect the small difference of proton and neutron masses (1.38 mmu) which though small compared to the total mass is not small compared to the energy values of the problem.

If this is done, we may separate the motion of the center of mass in the usual way and deal simply with the factor of the wave function which refers to the internal motions and depends on r, σ_1 and σ_2. The states of the system may be labelled by the values of orbital angular momentum and by resultant spin using the familiar spectroscopic notation in which orbital values are denoted by S, P, D, F for $L = 0, 1, 2, 3$ and denoting resultant spin values by superscript 1 (singlet) for $S = 0$ or superscript 3 (triplet) for $S = 1$. Since

$$\begin{aligned} 1\psi_{LS} &= \psi_{LS}, \\ H\psi_{LS} &= -(-1)^{L+S}\psi_{LS}, \\ M\psi_{LS} &= (-1)^{L}\psi_{LS}, \\ B\psi_{LS} &= -(-1)^{S}\psi_{LS}, \end{aligned}$$

the effective law $V_{LS}(r)$ for a state of orbital angular momentum L and spin S is

$$V_{LS}(r) = V_1(r) - (-1)^{L+S}V_H(r) + (-1)^{L}V_M(r) - (-1)^{S}V_B(r).$$

This gives four types of force law in the two-body problem:

$$\begin{aligned} {}^3S: \quad V_{01}(r) &= V_1 + V_H + V_M + V_B, \\ {}^1S: \quad V_{00}(r) &= V_1 - V_H + V_M - V_B, \\ {}^3P: \quad V_{11}(r) &= V_1 - V_H - V_M + V_B, \\ {}^1P: \quad V_{10}(r) &= V_1 + V_H - V_M - V_B. \end{aligned}$$

Since we know the resultant spin of the deuteron is 1, we know that the normal state of the deuteron must be one of the four possibilities ${}^3S_1$, ${}^1P_1$, ${}^3P_1$, or ${}^3D_1$. From the observed isotropy of the neutron scattering up to 5 mmu internal energy, we infer that the force laws are such that the radial wave function phase shifts δ_{LS} which determine the scattering according to the formula

$$\sigma(\theta)d\omega = \frac{\lambda^2}{16\pi^2}d\omega[\tfrac{1}{4}|\sum_L(2L+1)(e^{2i\delta_{L0}}-1)P_L(\theta)|^2 + \tfrac{3}{4}|\sum_L(2L+1)(e^{2i\delta_{L1}}-1)P_L(\theta)|^2]$$

are all essentially zero, except for $L = 0$, that is, δ_{00} for ${}^1S$ scattering and δ_{01} for ${}^3S$ scattering. In this case the total scattering cross-section reduces to

$$\sigma = \frac{\lambda^2}{\pi}[\tfrac{1}{4}\sin^2\delta_{00} + \tfrac{3}{4}\sin^2\delta_{01}].$$

Here λ is the de Broglie wave-length $h/\sqrt{2MW}$. If the law of interaction is such that the phase shifts for scattering for $L \neq 0$ are essentially zero, we can regard this as proof that the normal state of the deuteron must be a state for which $L = 0$ and hence must be ${}^3S_1$.

From general considerations about the binding energy of nuclei in general, we can conclude that the range of action of the specifically nuclear forces is of the order of 10^{-13} cm. and from the known binding energy of the deuteron can get an idea of the general character of the interaction law. The data are insufficient to distinguish between different similarly shaped analytical forms as Gauss error curves or square wells.

Simple calculations of Bethe and Peierls show that the scattering cross section is related to the binding energy by

$$\frac{\lambda^2}{\pi}\sin^2\delta_0 = \frac{(\lambda')^2}{\pi} \text{ where } \lambda' = \frac{h}{\sqrt{2M(\epsilon+W)}}.$$

Numerically this is

$$\sigma = 2.35\cdot 10^{-24}\frac{\epsilon}{\epsilon+W}\text{cm}^2.,$$

where ϵ is the binding energy of the deuteron and W is the internal energy of the scattering problem, half the incident neutron energy. For high energy neutrons this is an agreement with the facts, but does not agree with experiment for slow neutrons where $\sigma = 35 \cdot 10^{-24}$ cm^2. The answer is that this calculation tacitly supposes the law of force in the ^1S and ^3S states to be the same. Wigner pointed out that one can get agreement by supposing that the binding energy ϵ' of the singlet state is much smaller than ϵ for the triplet state. This gives for the scattering cross-section

$$\sigma = \left[\frac{3}{4}\frac{\epsilon}{\epsilon + W} + \frac{1}{4}\frac{\epsilon'}{\epsilon' + W}\left(\frac{\epsilon}{\epsilon'}\right)\right] 2.35 \cdot 10^{-24} \text{ cm}^2.$$

This agrees quite well with experiment if we suppose that

$$\epsilon' = 40000 \text{ ev.},$$

which implies, of course, a considerable difference between the singlet and triplet interaction laws.

An important and peculiar feature of quantum mechanics is that an attractive potential may not be strong enough to give a stable level—the zero-point energy may be greater than the depth of the well. We can see that this might be so from the formula

$$W = \int\left[\frac{\hbar^2}{2\mu}\left(\frac{\partial\psi}{\partial x}\right)^2 + V\psi^2\right]dx.$$

The second integral will be small if V represents a short range force unless ψ^2 is bunched up mostly into the region where V is large. But if this region is very small such a large degree of bunching up implies that the first integral is very large, making the first integral, which is essentially positive, be numerically larger than the second.

When this point is taken into consideration, it can be shown that the Wigner explanation of the large scattering cross-section for slow neutrons does not necessarily imply that the ^1S state of the deuteron is a stable state. If the well is not deep enough to give a stable state, the theory nevertheless, gives a formula of the same type for the variation with energy W of the scattering cross-section containing a parameter characteristic of the force law. A mode of speech has grown

up whereby this parameter is referred to as a "virtual level" if the force law is such that there is no stable level. This is apt to be confusing in that in case ϵ' corresponds to a so-called virtual level there is nothing very sharply characteristic about this energy value in the positive continuum.

It becomes an important question to determine whether the parameter ϵ' of the ^1S proton-neutron interaction law refers to a stable level or to a virtual level in the sense just explained. One cannot tell from the scattering data. The distinction is given by consideration of the phenomenon of photo-disintegration of the deuteron and its converse effect the radiative capture of neutrons by protons to form deuterons. The difficulty of the measurements has thus far prevented any very definite results from being obtained.

The question is involved in the theory of the difference between the scattering of slow neutrons in ortho and in para hydrogen as worked out by Schwinger and Teller. The experiments of Stern and associates, and also those made in Dunning's laboratory have given quite definite evidence of the virtual character of the ^1S level.

There is thus far no definite evidence concerning the ^1P and ^3P interaction laws for proton-neutron from direct study of two-body problems. These are involved in the theory of scattering of neutrons of much higher energy than any at present available and also in the theory of photo disintegration of the deuteron by high energy x-rays.

For proton-proton interaction, we have as essential data

(*a*) the absence of any evidence for a helium isotope of mass 2,
(*b*) the proton-proton scattering data obtained by Tuve, Hafstad, and Heydenburg up to incident proton energies of 900 kv., recently extended up to 2400 kv. by Herb and associates in Madison.[7]

Here we can use that same kind of formalism as was introduced for the interaction of protons and neutrons with this difference that there is no doubt connected with inequality of

[7] Tuve, Hafstad, and Heydenburg, *Phys. Rev.*, **49**, 402 (1936); Hafstad, Heydenberg, and Tuve, *Phys. Rev.*, **53**, 239 (1938); Breit, Condon, and Present, *Phys. Rev.*, **50**, 825 (1936); Cassen and Condon, *Phys. Rev.*, **50**, 846 (1936); Breit and Feenberg, *Phys. Rev.*, **50**, 850 (1936); Breit, *Rev. Sci. Inst.*, **9**, 63 (1938); Wheeler, *Phys. Rev.*, **50**, 643 (1936).

the masses, and secondly, that owing to the fact that the particles obey Fermi-Dirac statistics, the ^3S and ^1P laws are excluded (here we use S and P to symbolize all states of even and odd orbital angular momentum). This means that it is meaningless to express the interaction in terms of the four types introduced before. The two laws are

$$^1S: \quad V_{00} = V_1 - V_H + V_M - V_B,$$
$$^3P: \quad V_{11} = V_1 - V_H - V_M + V_B,$$

so we see that for proton-proton interaction the Heisenberg type is in principle indistinguishable from the ordinary type and the Bartlett spin exchange type indistinguishable from the Majorana type.

At present, the only information we have concerns the ^1S law of interaction. The proton-proton scattering data are fairly well represented by assuming that the departure from Coulomb law scattering is given entirely by the effects of the ^1S specific interaction. From this work, the most striking thing that emerges is the fact that the ^1S interaction of protons with protons is quite closely the same as the corresponding law for protons and neutrons. When one considers the work of Herb at higher energies, it appears that there are appreciable departures from the scattering to be expected solely from the effects of ^1S interaction. In this connection, it should be mentioned that there are other possibilities for interaction laws than those we have been considering, particularly forms involving the scalar product of each spin with the vector separation of the two particles which may be necessary to account for the high energy proton-proton scattering. All in all it seems that the careful extension of these scattering experiments to increasingly higher voltages with as great accuracy as possible is the most important fundamental experiment for which we can clearly see the need at present.

Let us turn now to a brief consideration of the information about interaction laws obtained from calculations on mass defects of the many-body nuclei. This is a very complicated subject in which approximation methods of doubtful validity mar the conclusions obtainable from laborious computations.

Work on the calculation of the energy levels of complex nuclei has been greatly stimulated in the last year by the con-

clusion drawn from the proton-proton scattering experiments that proton-proton and proton-neutron interactions are essentially alike in the ^1S states.[8] This makes it possible to use, in a fruitful way, a coördinate having two values $+1$ if the particle is a proton and -1 if it is a neutron. When this extra coördinate is introduced, the state of being a proton or a neutron is regarded as two quantum states of the same particle and the Fermi-Dirac statistics are applied by requiring the wave function to be antisymmetric in regard to proton-neutron exchange as well as in regard to proton-proton and neutron-neutron exchanges separately.

Introduction of this coördinate, which has been called isotopic spin by Wigner and the character coördinate by Cassen and Condon gives a convenient formalism for application of group-theoretic methods to the description of the possible low energy levels in isobaric nuclei. This point of view has been developed by Wigner and by Hund independently.

Breit and Feenberg first investigated the relation of the symmetrical Hamiltonian (in which the specifically nuclear forces are assumed to be independent of the character of the particle) to the statistical calculation of binding energies of heavy nuclei. This same point of view has been followed up in the Leipzig institute by Flügge, Volz, and Euler. In these calculations, the dependence of $V(r)$ on distance is assumed to be that of the Gauss error function

$$e^{-r2/a2},$$

where a is of the order of $e^2/mc^2 = 2.80 \cdot 10^{-13}$ cm. Volz' conclusion concerning the proportions of the four basic types of exchange force were later revised by Kemmer and at present the best supposition seems to be

$$V_M = \frac{10}{12} V_{01}, \qquad V_B = \frac{5}{12} V_{01},$$

$$V_H = -\frac{2}{12} V_{01}, \qquad V_1 = -\frac{1}{12} V_{01};$$

[8] Wigner, *Phys. Rev.*, **51**, 106 (1937); **51**, 947 (1937); Feenberg and Wigner, *Phys. Rev.*, **51**, 95 (1937); Feenberg and Phillips, *Phys. Rev.*, **51**, 597 (1937); Hund, *Zeits für Phys.*, **105**, 202 (1937); Wheeler, *Phys. Rev.*, **52**, 1083, 1107 (1937); Euler, *Zeits für Phys.*, **105**, 553 (1937); Volz, *Zeits für Phys.*, **105**, 537 (1937); Flügge, *Zeits für Phys.*, **105**, 522 (1937); Kemmer, *Nature*, **146**, 192 (1937); Wefelmeier, *Zeits für Phys.*, **107**, 332 (1937).

where V_{01} is the ^3S law which is the sum of the four types. This means that the binding forces are contributed by Majorana and Bartlett types, while the Heisenberg and ordinary types are repulsive and weaker.

It is interesting to consider the form assumed by the force law when the exchange operators are written in terms of the spin vectors σ_a and σ_b and the formally analogous isotopic spin vectors τ_a and τ_b. We have

$$H_{ab} = -\tfrac{1}{2}(1 + \tau_a \cdot \tau_b), \quad B_{ab} = +\tfrac{1}{2}(1 + \sigma_a \cdot \sigma_b),$$
$$M_{ab} = -\tfrac{1}{4}(1 + \sigma_a \cdot \sigma_b)(1 + \tau_a \cdot \tau_b).$$

On substituting these expressions and combining them in the proportions given above, one finds that the constant term and the term in $\sigma_a \cdot \sigma_b$ have zero coefficients, so the force law assumes the relatively simple form

$$V = Ae^{-r^2/a^2}(\tau_a \cdot \tau_b)[1 + \tfrac{5}{8}\sigma_a \cdot \sigma_b].$$

It appears from the simplicity of this result that the expression of exchange forces in terms of τ and σ is more fundamental than in terms of the previously introduced H, M, and B operators. The data are insufficient to determine the value of a except that it must be less than $2(e^2/mc^2)$ but for each assumed range, a, the value of A is quite accurately determined. The values $A = 4.75$ mmu and $a = 0.8\ (e^2/mc^2)$ give a satisfactory representation of data as known at present. The factor containing σ and τ has the values

Type	$(\tau_a \cdot \tau_b)(1 + \frac{1}{4}\sigma_a \cdot \sigma_b)$
^3S	-8
^1S	-4
^3P	$+8/3$
^1P	$+12$

It will be interesting to see whether future experiments on scattering with high energy particles are in accord with the conclusion that the forces are so strongly repulsive for odd values of orbital angular momentum.

(6) Finally, let us consider briefly the situation in regard to β disintegration and the field-theoretic interpretation of magnetic moments and specifically nuclear forces.[9]

[9] Wentzel, *Naturwiss*, **26**, 273 (1938); Yukawa, *Proc. Phys. Math. Soc. Japan*, **17**, 48 (1935); Yukawa and Sakata, *Proc. Phys. Math. Soc. Japan*, **19**, 1084 (1937); Critchfield and Teller, *Phys. Rev.*, **53**, 812 (1938); Kemmer, *Proc. Roy. Soc.*, **166**, 127 (1938); Frohlich, Heitler, and Kemmer, *Proc. Roy. Soc.*, **166**, 154 (1938).

As is well known, it has been necessary to invent the neutrino in order to balance the books in regard to energy, momentum spin and statistics in the β disintegration process. This way out was first suggested by Pauli and was made the subject of specific calculations by Fermi in 1934.

On this view, a nucleus emits a β particle as a result of a basic process in which a neutron is converted into a proton with simultaneous emission of an electron and a neutrino. Similarly, if a positron is emitted, the basic process is that in which a proton is converted into a neutron with simultaneous emission of an electron and a neutrino. The continuous spectrum of energies of the β particles emitted then arises from a statistical division of the constant total energy of the process between the observed electron and the unobserved neutrino.

In setting up such a theory, one has to make a definite postulate concerning the form of the term to be put in the Hamiltonian to bring about the transitions. To some extent the choices are restricted by requirements of relativistic invariance, but this still leaves a rather wide field of possible interaction forms available. Fermi chose one of the simpler forms in his first calculations; Konopinski and Uhlenbeck examined other possibilities, and especially emphasized the introduction of another form which they thought would give a theoretical distribution of energy in the β ray spectrum in better accord with experiment. This ambiguity as to possible interaction forms has caused a good deal of dissatisfaction with the electron-neutrino theory, but in this respect the theory is no worse than the phenomenological theory of specifically nuclear interactions. To its credit must be acknowledged a good measure of success in accounting for the shape of the β distribution function and for the relation between disintegration constant and upper limit of the energies which is exhibited in the Sargent curves. An important feature of this work is the recognition that disintegration constants of different orders of magnitude for the same upper limit can be satisfactorily correlated with an approximate selection rule on the angular momentum whereby large changes in spin of the nucleus during a β disintegration are improbable.

Soon after the electron-neutrino theory was first presented, it was hoped that it would provide a field mechanism for the

phenomenologically introduced nuclear interaction forces. This involves theory closely analogous to that whereby the Coulomb interaction of two charged particles may be regarded as taking place as a result of the coupling separately of each particle to the electromagnetic field. In the case of protons and neutrons, as discussed by Tamm and Iwanenko on the basis of the Fermi theory, the interaction arises from emission of a β particle and neutrino by the neutron which are absorbed by the proton. The net result is that the neutron becomes a proton and the proton a neutron, so the interaction provided by this mechanism is of exchange type. The calculations show, however, that the mechanism is inadequate to account for the observed forces by orders of magnitude—if the coupling of each heavy particle with the electron-neutrino field is made small enough to account for the observed β disintegration constants then it is much too small to provide the observed specifically nuclear interactions.

Likewise, it was thought that the electron-neutrino field might provide a mechanism for explaining the "anomalous" magnetic moments of proton and neutron. If a heavy particle like the proton spends a small part of its time as a neutron plus a positron and neutrino which are emitted and reabsorbed, then one can expect extra magnetic moment to arise in the time average because of the large magnetic moment of the positron. But these calculations are divergent just as in the case of the calculation of the self-energy of a charged particle which arises from its being coupled to the electromagnetic field. The proper handling of those divergent calculations in quantum electrodynamics and in the theory of the electron neutrino fields is a complete mystery which has baffled all attempts at resolution up to now. The solution of the mystery will probably call for an entirely new approach to these questions—at present, theory is up against a stone wall.

In the last couple of years, a number of suggestions for ways to provide a field theory for the nuclear forces have been actively studied. At present a good deal of interest attaches to a suggestion of Yukawa that the interaction results through a coupling of the heavy particles to a field of particles of intermediate mass—variously called heavy electrons, dynatons, barytrons, and Yukons. Yukawa postulated the existence of

particles of intermediate mass (100 to 300 times electronic mass) of integral spin and obeying Einstein-Bose statistics to provide a field by means of which protons and neutrons could interact. He showed that in the non-relativistic limit for the heavy particles this would provide an effective interaction potential whose range of action was of the order $\hbar/\mu c$ where μ is the mass of the new particle. Since $\hbar/\mu c$ for the electron is $380 \cdot 10^{-13}$ cm. it is seen that we must postulate the new particle mass to be 100 to 300 times the electronic to get agreement with the observed range of nuclear forces.

Since the whole field theory is being devised solely to account for the nuclear interaction forces, one is at liberty to take the coupling parameter large enough to get the observed magnitude as well as the observed range. Of course, this theory implies the existence of a new kind of radio-activity whereby a proton in the nucleus emits a positive Yukon and becomes a neutron (or conversely a neutron in the nucleus emits a negative Yukon and becomes a proton). But this would require that the initial nucleus have a mass greater than the resulting isobar by an amount in excess of the mass of the emitted Yukon—as no such cases are known, the absence of this type of radio-activity is explained. Perhaps if we can produce nuclei that are far enough away from the minimum energy on an isobaric line, this kind of radio-activity will be observed.

As long as the Yukawa calculations served merely to describe nuclear forces by *ad hoc* adjustment of its parameters, it was not regarded as anything but an interesting possibility. But since the recognition last year of the existence in cosmic radiation of particles of intermediate mass [10] it has attracted a good deal of attention for the possibility of correlating data from different experiments is thereby introduced.

It should be pointed out that the relativistic quantum mechanics always brings in automatically a particle of opposite charge—as in the theory of the positron and electron, so there is no need to postulate the existence of both kinds of Yukon as regards charge—if one is postulated you get the other one at no extra expense! But if one is to account for

[10] Neddermeyer and Anderson, *Phys. Rev.*, **51**, 884 (1937); Street and Stevenson, *Phys. Rev.*, **52**, 1003 (1937); Corson and Brode, *Phys. Rev.*, **53**, 215 (1938).

nuclear interaction of like particles by such a field, it is necessary to postulate also the existence of uncharged Yukons. The charged Yukons can give interaction between heavy particles of the same kind, but does so in a higher order calculation. This makes the apparent equality of proton-proton and proton-neutron interactions hard to understand. It seems better to assume in addition the existence of neutral Yukons whose coupling with the heavy particles is essentially the same as for the charged Yukons.

Finally, it should be mentioned that theories of this kind involve a careful reconsideration of our views of the interaction of the heavy particles with the electromagnetic field.[11] This comes about because the proton, at least, is not only directly coupled to the electromagnetic field, but both proton and neutron are indirectly coupled to it by means of the coupling of the charged Yukons to the electromagnetic field.

[11] Lamb and Schiff, *Phys. Rev.*, **53**, 651 (1938).

THE THEORY OF NUCLEAR STRUCTURE.

BY

E. U. CONDON, Ph.D.

DISCUSSION.

BY

DR. W. F. G. SWANN.

Of course, it would be possible to modify the potential function purely empirically to a form involving spins, and the like, and to secure an agreement with facts on this basis. It has always seemed to me that when such generalizations of forces are made as are involved in the "exchange forces" cited, the form of the generalization is itself made to assume a structure which anticipates the service it is intended to render. Thus, for example, to take classical electromagnetic theory, one may say that the ultimate problem is to determine the motion of any one electron in terms of all the others. However, if the motion were so expressed directly, it would assume a complicated form with no evident structure. In introducing the intermediary scaffolding of the Maxwell-Lorentz field, we introduce, directly *by definition*, quantities which, on the one hand, are simply, or at any rate harmoniously, related to the electrons which are responsible for producing the fields and, on the other hand, simply related to the motions of the electrons which the fields are regarded as producing. Field structure is itself a matter of definition; but in that structure are anticipated all the important characteristics of optical wave propagation, the directions of the forces necessary to result in polarization, and so forth. We can always eliminate these fields and, as I have said, express the forces directly between the particles as functions of their positions and motions, but then the vision of the power of the structure is lost. I should like to inquire what it is about the character of the "exchange forces" and about the form of their expression, which gives them special adaptability in anticipating the consequences required of them in a manner analogous to what I have tried to indicate in the case of the electromagnetic theory.

Fire Hazard of Radio Tubes.—The small compact radio, used by millions every day, is now eliminated as a fire menace in the home because of a startling, new radio tube invention, according to an announcement by Sayre M. Ransdell, vice-president of Philco Radio & Television Corp. "A revolutionary new all-glass radio tube, being introduced in a new line of compact radios by Philco," declared Mr. Ramsdell, "frees the small-size compact radio set from its classification as a fire hazard for the first time in the history of the radio industry. This invention, being made available to the entire industry, makes possible the manufacture of compact radios which, for the first time, bear the approval of the Underwriters' Laboratories, Inc., and fire insurance companies, as being safe from fire." The new all-glass Loktal tubes are being hailed as one of the most important developments in radio because of this safety feature and their smallness in size. Less than three inches in height, the Loktal tube effects an increase in efficiency and uses only half the power needed for the old-style tube. It also eliminates the ordinary base of the tube, thus being the first radio tube to be all tube. The small dimensions of these new tubes make possible the building of compact radios which offer the facilities and performance, as well as the safety, of radios many times their size.

R. H. O.

Lexicon of Geologic Names.—Definitions of the more than 10,000 named stratigraphic units in the United States and Alaska, which are scattered throughout the geologic literature of the past hundred years, have been summarized and brought together in one publication entitled "Lexicon of Geologic Names in the United States," published recently as Bulletin 896 of the Geological Survey, United States Department of the Interior. The definitions were assembled during a period of about 25 years by Miss M. Grace Wilmarth, the compiler of the lexicon, in her capacity of Secretary of the Survey's Committee on Geologic Names. All names that have appeared in geologic literature are included, regardless of whether they form a part of the official classification of the Federal Survey. Under each name is given the age, the general geographic distribution, the name of the geologist who introduced the name, the date of its introduction, and the reference to the paper in which it was proposed. Under each author's name is a digest of his original definition and description.

R. H. O.

PERMANENCE OF FINGER PRINTS.

BY

THOMAS COULSON, O.B.E.

The positive identification of individuals has at all times been a problem of vital importance for the maintenance of law and order. Descriptions of "wanted" criminals were employed by the police officials of Egypt in Ptolemy's day. In the Middle Ages criminals were punished by mutilation and branding, which may be regarded as the first attempt toward subsequent identification. When, in 1840, Lambert Quetelet, the Belgian statistician, announced that no two beings in the world were of exactly the same size in all respects, the warden of Louvain prison, a man named Stevens, tried to put the declaration to test by making measurements of heads, ears, feet, etc., of the criminals under his charge. But the actual invention of a system of identification founded upon Quetelet's theory, and the development of a technique of measurement was not undertaken until Alphonse Bertillon, of the Police Department of Paris, worked out the details.

Anthropometry was based upon three principles. First: that the human body does not change after the twentieth year, second: that no two human bodies have bones exactly alike, and third: that accurate measurements could be taken with simple instruments. Unhappily, two defects were revealed in these threefold principles. It was found that some bones did grow after the twentieth year, such as the thigh bone; but this was discounted by the compensating curving of the spine. More serious was the fallacy of the apparently innocent third principle. Experience proved that it was far from easy to make accurate measurements. There were marked differences in measurements made by different police departments, or even when a man was measured twice by the same official. Accuracy depended upon whether the measurement was close or loose, and, as there was no means of standardizing the method, anthropometry was far from fool-proof.

Worst of all, it applied only to adult criminals. The part played by growing youths between the years of 17 and 20 in criminal activities made this system of identification unsatisfactory.

Finally, came the science of Dactyloscopy, or Finger Printing. The use of finger prints as a means of identification was employed by the Chinese before the Christian era. They even developed a system of classification of finger prints for criminal identification.[1] But the first practical system was that devised by Sir Francis Galton and Sir Edward Richard Henry. The method of sub-classification by ridge tracing and ridge counting is too familiar to require explanation.

When this system was first introduced (at Scotland Yard in 1901) the defending attorneys protested that there was grave risk of identical finger prints existing. Galton [2] in his book showed mathematically that two identical prints could not exist. He calculated that 64,000,000,000 different patterns were possible. The universal adoption of the Galton-Henry system (with its extensions) and the filing of millions of prints by the Federal Bureau of Investigation in Washington, have proved that the mathematical reasoning is sound.

The second objection to finger prints, that they might change through the passage of time, was harder to prove. It was found that the ridge patterns formed after the fourth month of intrauterine growth and, while they continue to grow larger, they did not change in pattern. But did this hold true over a long interval of time? Sir W. J. Herschel had made prints of his hands over an interval of twenty-eight years. These showed absolute identity, but the time-span was not judged long enough to be conclusive. Another print of a friction ridge pattern had been made in 1856 by the German anthropologist, Welker, at Giesen. He was then thirty-four years old. In 1897, when he was seventy-four, Welker made a second print. There is an absolute identity between the two.[3]

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[1] Heindl, R., "System und Praxis der Dactyloskopie."

[2] Galton, F., "Fingerprints." London, 1892.

[3] Södermann, H., and J. J. O'Connell, "Modern Criminal Investigation." New York, 1935.

We now have further demonstration of proof extending over a longer time-span, and this time it comes from one of the oldest members of The Franklin Institute. On April 19, 1887, after a meeting of the Institute's Committee on Science and the Arts, a number of members adjourned, as was their custom, to Lauber's Rathskellar, at 9th and Filbert Streets. Here the learned discussions were continued in an informal manner until closing time. On this occasion Louis E. Levy, the well known photo-engraver, let fall the remark that he understood the palm and finger print patterns were formed in babyhood and remained unchanged until death. This casual remark made a deep impression upon the mind of a youthful member of the party, W. N. Jennings. That same night, on returning home, Mr. Jennings made an ink print of his palm, filed it away, and decided to wait for fifty years in order to ascertain whether Louis Levy was right in his declaration. Since Mr. Jennings had already announced his intention of living to be a hundred he left a reasonable margin of safety.

It is noteworthy that when this print was made there was very little known of finger printing outside a restricted circle. Dr. Henry Faulds, of the staff of the Tsukiji Hospital in Tokyo, had published an article on the subject in *Nature* in 1880, and Herschel had followed with another in the same journal, but the disputants in Lauber's Rathskellar can have had access to very little, if any, other literature. What, then, aroused Jennings' curiosity? He was no student of criminal investigation, but he had the enquiring mind of the research worker in the eternal quest for scientific proofs.

Although Mr. Jennings moved his wordly belongings a number of times since he first made a print of his hand, and although each removal involved the transportation of many things other than his household needs (several thousand photographic negatives, for example) he never lost sight of his palm print. On January 19, 1937, he carried out his resolution to make a comparison of prints after a lapse of fifty years. He made the second ink print of his right hand. The two prints are reproduced here.

This is the only known instance of prints made of the same hand at such a long interval of time. A careful examination

FIG. 1.

Ink print of W. N. Jennings' Right Hand, 1887. (Courtesy of the Institute of Applied Science, Chicago.)

FIG. 2.

Ink print of W. N. Jennings' Right Hand, 1937. (Courtesy of the Institute of Applied Science, Chicago.)

of the two will show that the pioneers of dactyloscopy were justified in saying that time does not efface or change the tell-tale ridge patterns.

Mr. Jennings' work is too well known to need recapitulation here, but note should be made that he received the Wetherill Medal from The Franklin Institute in 1930 for his photographs of lightning flashes. He is the third senior member of the Committee on Science and the Arts, in the activities of which he still takes a keen interest. He has yet to prove that he can live to be one hundred, but as things stand the odds look to be in his favor, for in the matter of this hand print, Mr. Jennings has given proof of his perseverance.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

THE NATIONAL BUREAU OF STANDARDS AS A SERVICE ORGANIZATION.

The Bureau's services to the National and State governments, American industry, and the general public were described in a brief address by Dr. Lyman J. Briggs, at a meeting of the National Electrical Manufacturers' Association held at the Department of Commerce on March 31.

Doctor Briggs spoke, in part, as follows:

"The National Bureau of Standards is a service organization. It has no police or enforcement responsibilities, nor does it desire such authority.

"One of the primary service functions of the Bureau is the custody and maintenance of the national standards of measurement. Industrial efficiency demands that the working standards of industry be kept in close accord with these national standards. To this end, the Bureau gladly undertakes for any person the testing of any standard or instrument, the correct use of which necessitates its comparison with the national standards. The law provides that such tests shall be made free for Federal and State agencies. For others a fee covering the cost of the work is charged. The importance of this service can hardly be over-emphasized. For example, the mass production of interchangeable parts in this country has been made possible through ceaseless checking of the working standards of industry with the national standards maintained at the Bureau.

"The Federal Government buys its supplies on the basis of specifications. Open competitive bidding, combined with a good specification, is the fairest method of making Federal purchases that has been developed. But there is another essential step in this procedure. The delivered goods must be tested to determine whether they fully meet the specifications. Such testing for other Government agencies represents

* Communicated by the Director.

a second large service activity of the Bureau. This should be extended, because the omission of acceptance tests by any purchasing agent defeats the whole procedure.

Federal specifications are written by committees of technical men drawn from all branches of the Government, working under the general guidance of an executive committee. The Bureau takes an active part in this work, along with other agencies, but all Federal specifications are fundamentally of an interdepartmental nature. Over 1200 of these specifications are now in effect. No specification in these days can safely be considered as a finished perfected thing. New products are coming into the market, new manufacturing processes are being used, new facts regarding materials are being established. Federal specifications are constantly being revised and strengthened in the light of these developments and new ones are being added.

"Research is the very foundation of the Bureau's work. Through research the national standards of measurement are extended, developed, made more exact. Better methods are devised for comparing the working standards of industry with the national standards. Research provides the basic information for writing new and better specifications. Through research more rapid methods of testing products are developed, including accelerated tests to determine the probable life and performance of a product in long-time service. Through research the essential and the characteristic properties of materials are determined. Facts established through painstaking research constitute a national heritage that can never be taken away, a foundation upon which we can safely build. No better national investment could be made than to extend this research service.

"Research enables the members of the Bureau's staff to speak with first-hand knowledge of their specialized subjects. The extent to which this knowledge is utilized and appreciated by industry may be illustrated by the results of a 3-day survey conducted last March. During this 3-day period 427 men came directly to the Bureau to consult members of the staff on technical matters. During the same period, 800 letters requesting technical information were received; 400 additional

letters requested Bureau publications; 800 calls for information came in by telephone.

"I close by repeating what I said in the beginning, the National Bureau of Standards is an organization of service—to the Federal and State governments, to industry and to consumers."

NEW UNITS OF ELECTRICITY AND LIGHT.

In pursuance of the program for establishment of new values for the units of electricity and light (*Technical News Bulletin 225;* January 1936, and 246; October 1937) the Bureau last year sent groups of standard cells and standard resistors to the International Bureau of Weights and Measures and standard lamps to the National Physical Laboratory of Great Britain, for comparison with similar standards from other countries. These standards have now been returned, and remeasurement at the Bureau shows that they remained very stable in value.

One of three standard resistors apparently changed in resistance by one part in a million, but the other two showed practically no change. Of 10 standard cells, none apparently changed by as much as 2 parts in a million. Such measurements give a very precise comparison with units now maintained in other countries, and also provide a basis for combining the results obtained in various countries on determinations of the values of the units by absolute measurements. The Bureau has reported results of its determinations (see following item, and *Technical News Bulletin 258;* October 1938), but the international program has fallen behind schedule, particularly because no reports on electrical units have been received from the German national laboratory.

The lamps compared at the British laboratory were of two types, one representing candlepower derived directly from the new primary standard (black-body radiator at the freezing point of platinum, 2046° K.), the other, candlepower of vacuum tungsten lamps at a color-temperature of 2360° K. On average values the agreement between the three laboratories taking part in the comparison is good, but further measurements are necessary to explain variations of results

on individual lamps so as to increase the certainty of the values. Comparisons of standards for flux of light (lumens) must also be made, and this must be extended to include lamps of the gas-filled tungsten type before the new units can be put into practical use.

Because of the delays in the international program it is evident that new values of the units cannot be introduced into use as of January 1, 1940, as was planned. Meetings of two committees dealing with the two classes of standards are to be held in Paris in June, and the International Commission on Illumination (which is concerned with the units of light) is scheduled to meet in Holland during the same month. It is expected that definite plans for the introduction of the new units can then be made and a new date set. The Bureau will then be prepared to recommend such legislation as is necessary to adopt the units in this country.

ABSOLUTE DETERMINATION OF THE AMPERE.

The measurements which have been made at the Bureau to establish the value of the unit of electrical current, the ampere, in terms of the mechanical units of length, mass, and time have been referred to in previous numbers of this *Bulletin* (192, April, 1933 and 206, June, 1934). The current balance as used in this work is an apparatus consisting of a coil suspended from the pan of a very sensitive balance and two larger coils attached to the case of the balance; one above, the other below, the suspended coil. The dimensions of these coils and their distance apart must be accurately measured. When the coils are carrying a current, the force on the suspended coil can be measured by the balance. From this force and the known geometrical arrangement of the electrical circuits the current can be computed. The current so obtained is said to be expressed in absolute amperes. The absolute ampere in connection with the absolute ohm are used to determine the electromotive force of a standard cell in absolute volts.

In the *Journal of Research* for May, a report (RP1200) by Harvey L. Curtis, Roger W. Curtis, and Charles L. Critchfield, gives the details of measurement and the results

obtained with improved coils. The coils of one set, which were wound with anodized aluminum ribbon, were much more compact than any previously used. The result obtained, however, is only slightly different from that obtained in the previous investigation.

CADMIUM-CADMIUM SULFATE HALF-CELL FOR MEASURING POTENTIALS IN THE EARTH.

In the control of stray currents from electric railways and in the design and regulation of cathodic protection circuits, it is frequently desirable to measure the potentials of buried structures with respect to a reference electrode which is in contact with the soil. The copper-copper sulfate half-cell, described in the April number of this *Bulletin*, is used for this purpose, but it has the disadvantage that the measured potential difference between the half-cell and iron is usually rather large, being approximately 0.6 volt. If the potential difference between the iron structures and the reference electrode were smaller field potential measurements could be made more conveniently. The cadmium-cadmium sulfate half-cell has a potential near that of iron in the average soil. An investigation was therefore made by Scott Ewing, research associate of the American Gas Association at the Bureau, to determine whether this half-cell would be suitable in other respects for field measurements.

It was found that cadmium is considerably more stable in potential behavior than copper and that cadmium electrodes, plated with spongy cadmium, are reproducible within 0.25 mv. The difference in potential between two cadmium-cadmium sulfate half-cells was measured when one of the half-cells was held at constant temperature while the temperature of the other was varied over the range from 0° to 50° C. These measurements were made using 10 per cent. $CdSO_4$ and saturated $CdSO_4.8/3H_2O$ solutions. By means of the observed relation between temperature and potential, potential measurements between two half-cells may be corrected to a common temperature. Polarization on various kinds of cadmium electrode surfaces in contact with several concentrations of cadmium sulfate was measured over the current

density range which would be used in practice. The error caused by polarization can be reduced to 1.0 mv. at most by the use of spongy cadmium, provided the current density does not exceed 0.16 ma. per sq. cm.

From consideration of these data and the currents required for the operation of suitable deflection instruments, a half-cell for field use was designed. The arrangement and form of the half-cell are the same as that of the copper-copper sulfate half-cell previously described.

DISTRIBUTION OF OZONE IN THE STRATOSPHERE.

Measurements of the spectral quality and total intensity of ultraviolet solar radiation at a fixed ground station as well as similar measurements obtained at various elevations above the earth's surface are reported in a paper (RP1207) by W. W. Coblentz and R. Stair in the *Journal of Research* for May.

For making measurements at a fixed ground station at a high elevation (Flagstaff, Arizona, elevation 2.2 km.) a portable ultraviolet intensity meter, consisting of a balanced amplifier, Ti-photoelectric cell, and microammeter was used (*B. S. J. Research*, **12**, 231 (February, 1934), RP647).

For measuring solar radiation in the stratosphere an ultraviolet intensity meter (consisting of a Cd-photoelectric cell and filter radiometer connected with a balanced amplifier, relaxation oscillator and radio transmitter) and a radio-operated barometer were transported aloft by means of unmanned balloons. The audiofrequency modulated radio wave, giving the intensity of the ultraviolet solar radiation and the altitude of the apparatus, was received and graphically recorded at a fixed ground station (*J. Research N. B. S.*, **20**, 185 (February, 1938), RP1075).

In the measurements at Flagstaff, Arizona, close parallelism was observed in the variation in filter transmission with variation in barometric pressure, in agreement with the well-known variation in the amount of atmospheric ozone that accompanies changes in air pressure. No such systematic variation in filter transmission with variation in pressure of atmospheric aqueous vapor was observed.

A notable example is described where the wave of low

barometric pressure preceded, by 5 to 6 hours, an appreciable increase in atmospheric ozone; apparently indicating which was cause and which was effect, and suggesting a method of studying air circulation in the stratosphere.

In four balloon ascensions, made in June 1938, the photoelectric ultraviolet intensity meter and auxiliary radio transmitting apparatus attained heights of 25 to 27 km. (83,000 to 88,000 feet), penetrating about 65 per cent. of the ozone, most of which was localized in a layer extending from an elevation of 18 to 27 km., with a wide maximum of concentration at a height of about 25 km. At the highest elevation attained by the instruments, the intensity of the ultraviolet of short wave lengths was about 10 times that of direct sunlight at sea level.

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pH VALUES OF PAPERS.

The acidity of a paper, expressed as its pH value, is now considered one of the most important items on which to base an estimate of its lasting qualities. A relatively acidic paper will deteriorate despite any other properties it may have. The Government, in buying record paper, accordingly requires that the pH value must meet a certain specification. It is, therefore, very important that a method of measuring the pH be available which will give values as reproducible as possible. Unfortunately, the methods in use at the present time, have been found to give results which sometimes differ widely.

An improved method has been developed by Herbert F. Launer at the Bureau which is rapid and has good reproducibility. It requires far less handling of the papers than previous methods, thus decreasing the probability of obtaining misleading results through contamination. Extraction is made at room temperature, since no advantage of using hot water, as prescribed by the method generally used, could be found.

Reports on the method, given in RP1205 in the May *Journal of Research*, show that the pH values obtained by the new procedure are in good correlation with the chemical stability and with the percentages of alum used in the manufacture of the papers, and may, therefore, be said to represent

the quality of the papers adequately. In studying these relationships, many varieties of experimental papers were used, which had been produced under carefully controlled conditions in the Bureau's semi-commercial paper mill.

FLAME PROOFING OF TEXTILES.

For certain uses textiles must be rendered as nearly fire resistant as possible, and inquiries about methods for accomplishing this are frequently received at the Bureau. A new method has been developed for making fire tests of textiles in which a 7 by 1 inch sample of a vertical edge is exposed to the flame. The testing method and recommended requirements were incorporated in a report to the Committee on Fire Proofing and Preservative Treatments of the National Fire Protection Association. Twenty samples of heavy cotton felt and 27 samples of cotton duck have been tested by this method at the request of the Procurement Division of the Treasury Department. Federal Specification CCC–D–746 entitled "Duck, Cotton; Fire, Water, and Weather Resistant" was issued during the month, the flame proofing requirements being based on tests conducted during the past year.

ECONOMIC FEATURES OF X-RAY PROTECTION.

A study of the International Recommendations for X-ray Protection shows that while they are self consistent, they are too stringent for most conditions encountered in the usual hospital practice. Since the lead walls form a major part of the installation cost of an X-ray department, any permissible economies therein should be welcome. Based on recent studies by Lauriston S. Taylor at the Bureau, concrete walls and floors were found to provide adequate protection when used in sufficient thickness. For higher voltage ranges, costs may be reduced to 1/10th by using concrete instead of lead walls, but for voltages below 200 kv. the use of lead may be economically advantageous. By considering the decrease in intensity of the X-rays with the distance from the X-ray tube, further substantial reductions in the protective walls

may be made. While scattering of X-rays from a patient forms an important source of secondary radiation, its intensity has been over-estimated. By considering the actual intensity and penetration of the scattered rays, the side protective walls may usually be reduced far below the thicknesses called for in the International Recommendations. The penetration of the X-rays is also decreased rapidly when they are scattered at right angles to their original direction (Compton effect). This has not been previously considered from the economic point of view, whereas its recognition permits substantial savings in any protective walls. In general it is found, as compared with the International Recommendations, that at 200 kv., costs may be reduced to 1/5th, and at 400 kv. to 1/10th in new X-ray installations.

Long Time Weather Charts Indicate Drought Cycle Temporarily Halted.—The years just ahead will average relatively wet, if the weather pattern of the past century continues. The annual report of the U. S. Weather Bureau explains that weather history is a succession of dry and wet cycles, interspersed with periods of about average precipitation. The Bureau warns against a false optimism that disregards future droughts however. The successions of long-continued dryness are irregular and their coming can not be forecast by any methods yet known to meteorologists. Many investigators believe there is a useful relationship between weather conditions over the continents and those that precede them over the oceans. Although the Weather Bureau has on file long-time weather histories for the continental United States, it has had no comparable histories for adjacent ocean areas. Marine observations made in the past, but never tabulated, have only recently been compiled. Included in the general weather and crop-reporting research of the year were investigations of cold waves in North America, a study of warm and cold anticyclones, and an effort to determine the part ozone may play as a link between solar activity and atmospheric change. It is hoped that the results of this research will be valuable in developing long range forecasting methods. The gap between the practical and the theoretical school of forecasting—apparently incapable of being bridged when observations were confined largely to surface conditions—has steadily narrowed as modern means for exploring the upper air have given meteorologists more information on the movement of free air up to great altitudes.

R. H. O.

Air Filter Research at Mellon Institute.—Dr. Edward R. Weidlein, Director, Mellon Institute, Pittsburgh, has announced the the establishment of an Industrial Fellowship in that institution by the American Air Filter Company, Inc., of Louisville, Ky. This fellowship will investigate broadly materials of value in the construction of filters for air-conditioning systems. It will be the aim to gain through this research new knowledge to effect all possible improvements in the devices manufactured by the donor, and in this work the Fellowship will have the direct coöperation of specialists on the staff of the Multiple Industrial Fellowship on air hygiene in operation in the Institute. Dr. Frank F. Rupert, who has been appointed to the incumbency of Fellowship, has been a member of Mellon Institute since 1913.

R. H. O.

THE FRANKLIN INSTITUTE

MEDAL DAY MEETING,

MAY 17, 1939.

The annual Medal Day meeting was held this afternoon at 3:30 o'clock with Mr. Philip C. Staples, President, in the chair.

The minutes of the previous meeting were approved as published in the current issue of the JOURNAL. The several awards recommended by the Committee on Science and the Arts were then made as follows:

	Sponsor
Presentation of Certificate of Merit, jointly to PERCY RUSSELL, D.D.S., Wilmington, Delaware.	Mr. James D. Lee, Jr.
E. BURKE WILFORD, President, Pennsylvania Aircraft Syndicate, Philadelphia, Pennsylvania.	
Presentation of Longstreth Medals to ARTHUR C. HARDY, SC.D., Professor of Optics and Photography, Massachusetts Institute of Technology, Cambridge, Massachusetts.	Mr. Lewis P. Tabor
JESSE E. STARECK, PH.D., Technical Director, Electrocolor Division, United Chromium, Incorporated, Waterbury, Connecticut.	Dr. Julian W. Hill
JOHN STRONG, PH.D., Assistant Professor of Physics in Astrophysics, California Institute of Technology, Pasadena, California.	Mr. James Stokley
ROBLEY COOK WILLIAMS, PH.D., Department of Astronomy, University of Michigan, Ann Arbor, Michigan.	Mr. James Stokley
Presentation of Wetherill Medal to WILLIAM ALBERT HYDE, Director of Research, Leon J. Barrett Company, Worcester, Massachusetts.	Mr. Samuel Shoemaker

Presentation of Henderson Medal to
RALPH BUDD, President,
Chicago, Burlington & Quincy Railroad Company,
Chicago, Illinois. — Dr. Rupen Eksergian

Presentation of Levy Medal to
KALMAN JOHN DEJUHASZ,
Associate Professor of Engineering Research,
Pennsylvania State College,
State College, Pennsylvania. — Mr. William G. Ellis

Presentation of Potts Medal to
NEWCOMB K. CHANEY, PH.D.,
Director of Research,
United Gas Improvement Company,
Philadelphia, Pennsylvania. — Dr. Hiram S. Lukens

H. JERMAIN CREIGHTON, SC.D.,
Professor of Chemistry,
Swarthmore College,
Swarthmore, Pennsylvania. — Mr. Charles H. Masland, 2nd

Presentation of Cresson Medals to
GEORGE ASHLEY CAMPBELL, PH.D.,
Research Engineer (Retired),
American Telephone & Telegraph Company,
Upper Montclair, New Jersey. — Dr. Thomas D. Cope

JOHN R. CARSON, D.SC.,
Research Mathematician,
Bell Telephone Laboratories, Incorporated,
New York, New York. — Mr. Stuart Ballantine

CHARLES VERNON BOYS, F.R.S., LL.D.,
London, England. — Dr. Charles B. Bazzoni

Presentation of the Franklin Medal and Certificate of Honorary Membership to
EDWIN HUBBLE, PH.D., D.SC., LL.D.,
Mount Wilson Observatory,
Carnegie Institution of Washington,
Pasadena, California. — Dr. James Barnes

Presentation of the Franklin Medal, posthumously, to
ALBERT SAUVEUR, SC.D., D.ENG.,
Professor Emeritus, Metallurgy and Metallography,
Harvard University,
Cambridge, Massachusetts.
Received by Mrs. Sauveur. — Dr. James Barnes

Paper.

"The Motion of the Stellar System Among the Nebulae"
by
DR. EDWIN HUBBLE

Adjourned.

HENRY BUTLER ALLEN,
Secretary.

(An extended account of the proceedings of Medal Day will be published in an early issue of the JOURNAL.)

INSPECT SISTER MUSEUM.

Members of the Board of Managers of The Franklin Institute recently attended a preview of the Chicago Museum of Science and Industry as guests of Mr. Lessing J. Rosenwald of Wyncote, son of the founder of the Museum. This great new institution is sponsored by The Commercial Club of Chicago.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of Stated Meeting held Wednesday, May 10, 1939.*)

HALL OF THE COMMITTEE,
PHILADELPHIA, MAY 10, 1939.

MR. WILLIAM G. ELLIS *in the Chair.*

The following report was presented for final action:

No. 3046: Work of Frederick M. Becket.

This report recommended the award of an Elliott Cresson Medal to Frederick M. Becket, of New York City, New York, "In consideration of his outstanding achievements in the development of processes for the production of low carbon ferro alloys, which have led to the wide use of many of the now well-known alloy steels, particularly low carbon stainless steels, and the higher chromium oxidation-resistant steels; and also for his many inventions and contributions in the field of electrometallurgy."

JOHN FRAZER,
Secretary to the Committee.

LIBRARY NOTES.

The Committee on Library desires to add to the collections of the Institute any technical writings of members who have had occasion to publish such material.

Literary contributions from author-members will be gratefully acknowledged, properly inscribed and noted in the Journal of the Institute.

Photostat Service. Photostat prints of any material in the collections can be supplied on request. Orders received in the morning are filled the same day. The cost for a print 9 × 14 inches is forty cents.

The library and reading room are open daily from nine o'clock A.M. until five o'clock P.M. Saturdays until 12 o'clock noon. 793 readers made use of the facilities during the twenty-four days of April.

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NOTES FROM THE BARTOL RESEARCH FOUNDATION.

THE ELECTRODYNAMIC FORCE EQUATION IN ITS BEARING UPON THE EVIDENCE FOR THE EXISTENCE OF A NEW COSMIC-RAY PARTICLE.*

BY

W. F. G. SWANN.

The evidence for the existence of a new cosmic-ray particle goes back, ultimately, to measurements whose interpretation depends upon the force equation

$$(d/dt)(m\mathbf{u}) = e(\mathbf{E} + [\mathbf{uH}]/c), \tag{1}$$

where $\mathbf{E}$ and $\mathbf{H}$ are the electric and magnetic fields, $\mathbf{u}$ the velocity, e the charge, and m the relativistic mass of the particle, and where c is the velocity of light. The mass m is related to the rest mass m_0 by the equation

$$m = km_0,$$

where

$$k = (1 - \beta^2)^{-1/2} \quad \text{and} \quad \beta = u/c. \tag{2}$$

Equation (1) conserves $T - e(\mathbf{E}\cdot\mathbf{u})$ where

$$T = (k - 1)m_0c^2. \tag{3}$$

T is the kinetic energy of the particle. In the case where $\mathbf{E}$ is zero, T itself is conserved.

Equation (1) is relativistically invariant, and would remain so if the right-hand side were multiplied by an invariant J. Moreover, in this case it would still follow that T as given by (3) would be conserved for $\mathbf{E} = 0$. In other words k would be conserved for this case. Let us replace (1) therefore, by

$$(d/dt)(m\mathbf{u}) = Je(\mathbf{E} + [\mathbf{uH}]/c). \tag{4}$$

It is our purpose to show that invariants J can be constructed which would be unity for particles of low velocity

* Reprinted from the *Physical Review*, **52**, 387 (1937).

moving in a pure magnetic field but which would differ from unity as the velocity of light is approached. The presence of such an invariant in the force equation would result in erroneous conclusions as to the rest mass being drawn by an interpretation of experimental results which neglected the invariant.

The product of any two 4-vectors gives an invariant. 4-vectors may be constructed from the field, as in the case of the 4-vector comprising the three components of the vector potential and the scalar potential, or they may be constructed from the motional elements alone. It is not our intention to determine a unique invariant to attach to the force equation, but simply one which *illustrates* our contention.

For our 4-vector material we may consider the 4-vectors I_1, I_2, etc., given in Table I, where $ds \equiv dt/k$, and where,

TABLE I.
Specifications of 4-vectors.

4-vector.	Components.				Degenerate Forms.	
	x.	y.	z.	4th.	Resultant 3-vector.	4th Component.
I_1.....	ku_x	ku_y	ku_z	kic	$kr\omega$) ↓	kic
I_2.....	$(d/ds)(ku_x)$	$(d/ds)(ku_y)$	$(d/ds)(ku_z)$	$(d/ds)(kic)$	$k^3r\omega^2$ ←)	0
I_3.....	$(d^2/ds^2)(ku_x)$	$(d^2/ds^2)(ku_y)$	$(d^2/ds^2)(ku_z)$	$(d^2/ds^2)(kic)$	$k^3r\omega^3$) ↑	0
I_4.....	$(d^3/ds^3)(ku_x)$	$(d^3/ds^3)(ku_y)$	$(d^3/ds^3)(ku_z)$	$(d^3/ds^3)(kic)$	$k^4r\omega^4$ →)	0
I_5.....	etc.	etc.	etc.	etc.	$k^5r\omega^5$) ↓	0

under degenerate forms, we have given the values to which the resultant 3-vectors, and the 4th components degenerate for the case where the particle moves in a pure magnetic field, so that, as already stated, k is conserved in spite of the incorporation of the invariant J in (4). Here ω stands for angular velocity, and r, for radius of curvature.

The arrows give the direction of the resultant degenerate 3-vector for a clockwise motion along the element of path shown.

The scalar product of any of the two 4-vectors listed gives an invariant. However, we can readily see from the direction of the degenerate 3-vectors and from the fact that

all the 4th components are zero except the first, that any scalar product of a 4-vector of odd order with one of even order is zero. Only scalar products of odd or of even 4-vectors survive, and these are obtained immediately in degenerate form by multiplying together the corresponding quantities in the column next to the last.

Now consider the invariant I defined by

$$I = [(I_1 \cdot I_3)^{7/4}]/[(I_3 \cdot I_5)^{3/4}].$$

It is, of course, zero when the velocity is zero, or as a matter of fact, when certain of the higher derivatives are zero. It degenerates to $-kr^2\omega$, i.e., to $-kur$ for the case of a pure magnetic field. Thus, if we should write for J

$$J = 1 - a_1 I + a_2 I^2 \cdots \text{etc.},$$

our invariant would degenerate, for a pure magnetic field, to

$$J' = 1 + a_1 kur + a_2 k^2 u^2 r^2 + \cdots,$$

where, of course, the a's are constants which may be positive or negative, and u for motion in the pure magnetic field is constant and is, as a matter of fact, nearly equal to c for high energy particles.

Equation (4) leads, for the case of a pure magnetic field, to

$$m_0 k(u^2/r) = J' uHe/c$$

or writing $m_0 ku$ as the resultant momentum M *of the particle*, we have

$$\frac{M}{r} = \frac{J'He}{c} = \frac{He}{c}\left(1 + \frac{a_1}{m_0} Mr + \frac{a_2}{m_0^2}(Mr)^2 + \cdots\right).$$

Now by a suitable choice of the a's, we can make the coefficient of H/c practically any function of Mr we please. Thus, we can make it decrease with Mr indefinitely, as it would do if we chose the a's so as to make it e^{-Mr}. We can make it decrease with Mr and approach asymptotically some value different from unity. Thus, suppose that it approached asymptotically the value 0.25. Then if one measured the curvature of a high energy particle in a magnetic field and neglected the faster J', he would find a value of M too large

by a factor of 4.[1] The extent of the error in M would depend upon Mr and these errors would reflect themselves upon the rest mass, if there were other means of arriving at the velocity. They would, in fact, tempt one in certain cases to predict a continuous range of rest masses.

It is to be observed that J' depends upon M *and* r. This would mean that for the same M, we could, by altering H, realize a different value of J'. Under these conditions, if we should allow the same particle to pass through different magnetic fields and measure its momentum by cloud chamber observations in each case, we should, if we used the classical equation without J', obtain two different values for the apparent momentum. An experiment founded upon this principle should serve to test the idea here tentatively proposed.

It is perhaps worth while to point out that the classical electrodynamic equation has no very reputable ancestry such as would be likely to protest against the modification here suggested. Its origin, along with the electromagnetic equations from the Lagrangian equations, is simply a result of the adjustment of the relativistic Lagrangian function to a form designed to give that end. The fact that the Schroedinger equation leads to it as a statistical result applicable to the motion of a wave pocket applies, as far as I know, only to the case where relativistic considerations are neglected, and so has no bearing upon the problem here considered. There appears to be no case where the modification here suggested would come into conflict with principles already established.

In weighing the possibilities inherent in the foregoing considerations, one must attend to certain matters. S. H. Neddermeyer and C. Anderson,[2] by measurements of deviations in a magnetic field, have divided cosmic-ray particles into two categories, those associated with showers, and those associated with single rays. While the points of their graph are very scattered, there is a reasonably definite indication that the shower particles lose energy more rapidly in passing through matter than do the single particles; and the energy

[1] This matter has significance in relation to the particles of apparently abnormal mass reported by Street and Stevenson, Abstract no. 40, Meeting of the American Physical Society, Apr. 29, 1937.

[2] S. H. Neddermeyer and C. Anderson, *Phys. Rev.*, **51**, 884 (1937).

loss for the former is consistent with the Bethe-Heitler theory. Anderson's measurements are interpreted in energy through the assumption of the normal electronic mass. If, therefore, we admit that two particles can show the same magnetic field deviation, but lose energy differently in passing through matter, we are in some difficulty, at first sight at any rate, in avoiding recognition of the existence of two different kinds of particles. It is true that the invariant in our force equation can be periodic in character, so that it does not change monotonically with the velocity; and, if such were the case, one could have particles of different energy showing the same magnetic deflection and with the same rest mass. However, such an assumption seems rather radical in scope. The alternative is to admit that there is more than one kind of particle and then the advantage of providing for the constancy of the mass in the various particles becomes dubious. One could, of course, have the constant a's in the expression for J dependent upon the spin, or indeed an invariant might be constructed which involved the spin more obviously. In either case one would insure a condition in which, although the particles had the same charge, the same rest mass, and obeyed the same laws for production of ionization, they had different force equations.[3]

It may be of interest to observe that if the force equation does in actuality involve an additional invariant J of the kind we have discussed in relation to the mass of the particle reported by Street and Stevenson, we should, in general, have a situation in which the energy as measured without regard to that invariant would be in error by a factor which increased with increase of the energy. The result would be that percentage losses in passing through lead divided by the average energy in the lead would come out too small; and, consequently, the apparent increase of energy loss with energy would come out too small.

One cannot help contemplating whether considerations of the foregoing kind may not have a bearing upon the evidence for the existence of the neutrino, since such evidence comes ultimately from the measurements of kinetic energies of

[3] It must be remarked, however, that a modification of the force equation of the kind cited might permit even a proton of high energy, and consequently of low ionizing power, to masquerade as the particle reported by Street and Stevenson.

electrons through assumption of the classical force equation. If the invariant J were incorporated, it would not be $T - e(\mathbf{E}\cdot\mathbf{u})$ which would be conserved. We should, in fact, have

$$(1/J)(dT/dt) = e(\mathbf{E}\cdot\mathbf{u}).$$

It is true that the neutrino manifests itself in connection with particle energies far below those concerned in cosmic-rays, energies comparable with a million electron volts. It is to be observed, however, that there is nothing to require that J should change monotonically with increase of the velocity of the particle.

It must further be pointed out that there is little to *necessitate* regarding the ordinary expression (3) as having anything to do with the quantity which we speak of in energy transitions in atomic structure problems. The assignment of energy levels in atoms, and the subsequent determination of frequencies by their differences, for example, are things which do not involve T as given by (3) having any relation to that which should be conserved in the processes involved. The energy magnitudes concerned in atomic structure problems come, for the most part, from a consideration of magnitudes of constants which determine the characteristic solutions of ψ equations. It is quite true that experiments on critical potentials and the like form a bridge between kinetic energy as born of the force equation and energy as it occurs in problems of atomic structure; but this bridge can hardly be considered to have been established for energies as high even as a million electron volts. However, it is not our purpose here to stress to the realm of the neutrino the considerations here presented. The main purpose of the paper concerns the cosmic-ray particles.

THE ENERGY FLUX OF THE CORPUSCULAR COSMIC RADIATION.*

BY

C. G. MONTGOMERY AND D. D. MONTGOMERY.

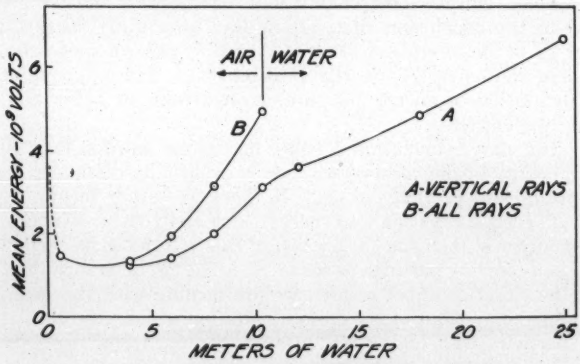
The recent advances in cloud chamber technique have made possible the measurement of such high energies of

* Condensed from a paper which was published in full in the *Physical Review*, 53, 193 (1938).

cosmic-ray corpuscles that one is led to inquire how much of the total energy of the cosmic radiation appears in a measurable form in the cloud chamber. It is possible to estimate the total flux of cosmic-ray energy across a unit surface, since all of this energy must eventually appear at points below the unit surface in the form of ionization and the excitation of atoms. Thus if we know the ionization at each point below our surface, we can integrate it and so obtain the total flux of energy through the surface. If we know also the number of corpuscular rays, we can obtain the mean energy per ray at any point. This can then be directly compared to the cloud chamber observations.

The values of the mean energy found from the ionization data are illustrated in Fig. 1. Curve A gives the mean

FIG. 1.



The mean energies of cosmic-ray particles at various depths in the atmosphere.

energy of the vertical rays, curve B the mean energy of all the rays crossing a horizontal square centimeter. It will be noted that the mean energy increases with increasing h. This is representative of the fact that there is a distribution of energies in the primary cosmic radiation, since the mean energy of the rays produced by a primary of a given energy must always decrease with increasing h. The mean energy at 0.664 meter below the top of the atmosphere is 1.46×10^9 volts, and since the earth's magnetic field excludes vertically

incident rays of energy less than 6×10^9 volts, the mean energy must increase to some value of this order at the top of the atmosphere. This rise is indicated by the dotted portion of curve *B*.

For the cloud chamber observations, we chose those of Blackett who measures the energy distribution of the vertical rays up to energies of 2×10^{10} volts. Using his energy distribution, one finds that the total energy of the 1015 rays of energy less than 2×10^{10} volts is 2.44×10^{12} volts. He observes in addition 42 rays of energy greater than 2×10^{10} volts, which must have a total energy greater than 0.84×10^{12} volts. Therefore the mean energy will be somewhat greater than $(2.44 + 0.84) \times 10^{12}/1057$, or 3.11×10^9 volts. This may be compared directly to the value calculated for vertical rays at sea level, *viz.*: 3.04×10^9 volts.

These figures agree closely with each other, and we are led to the conclusion that, *at sea level, practically all of the energy in the cosmic-ray beam is carried by charged corpuscles.* These figures rule out the possibility of any appreciable contribution of energy by photons, neutrons, or other non-ionizing entities.

The above conclusion is based on the assumption that all the energy of the cosmic radiation is eventually dissipated in ionizing and exciting atoms. If there are other means by which cosmic rays can lose energy, such as by the production of neutrinos, then the energy lost in this way must be carried by non-ionizing particles at sea level. The circumstance that, in the cloud chamber results, we are dealing with the penetrating component of the cosmic radiation which may consist of particles with higher rest masses than electrons, has only a very small effect on the measured energies, since the energies under consideration are high compared to the rest mass of the particles. The condition that most of the energy be carried by charged corpuscles would not obtain on the present theory of the passage of a beam of high energy electrons and their secondaries through matter. In that case we should expect approximately equal amounts of energy to be carried by electrons and by photons. If suitable cloud chamber observations were available, taken at a high elevation, this point could be directly tested, as has been done above for sea level.

ARTIFICIAL RADIOACTIVITY PRODUCED BY COSMIC RAYS.*

BY

W. E. RAMSEY, C. G. MONTGOMERY AND D. D. MONTGOMERY.

In a recent paper[1] having the above title, Clay and Van Tijn have reported observations which they interpret as evidence for radioactivity produced by the cosmic radiation. These observers have reported that when 5 tons of iron were placed over an ionization chamber as a shield of 55 cm. thickness, the ionization did not immediately decrease to its final value, but decayed exponentially with a half-value time of 8.6 minutes.[2] The value of the ionization ten minutes after the operation of moving the iron was started was 1.75 times the final value. We have endeavored to observe this phenomenon under conditions such that any possible effects of the mechanical stresses produced by the movement of large masses would be avoided.

A layer of 23 Geiger-Müller counters whose cylinders were 20 cm. long and 1 cm. in diameter was placed immediately below the top of an enclosure shielded with approximately 25 cm. of lead, a space being left below the counters for the insertion of four plates of iron 22 by 28 cm.^{2} and 1.27 cm. thick. The pulses from the counters were equalized and made to discharge a condenser. This condenser was recharged every 30 seconds, and the ballistic throw of a galvanometer caused by the charging current was observed. The plates of iron were placed side by side outside the shield, and observations were started. After a time the plates were piled beneath the tray of counters under the shield, observations being made continuously. Had any radioactivity been produced in the iron, the counting rate should have increased upon the introduction of the iron and then decayed exponentially. No change in the initial counting rate was observed, within the probable error of 1.5 per cent.

We should expect the percentage increase in the counting rate to be proportional to the change in the cosmic-ray

* Reprinted from the *Physical Review*, **53**, 196 (1938).

[1] J. Clay and M. S. Van Tijn, *Physica*, **4**, 909 (1937).

[2] Clay and Van Tijn state that the "time of decay" is 8.6 minutes. We interpret this to be the value of the half-life.

intensity produced by the shield, and to the thickness of the iron from which the radioactive radiations can reach the counters. We determined the change in cosmic-ray intensity caused by the shield by placing another layer of counters similar to the first as close as possible (5 cm.) below the first layer, and counting the coincidences between the two. The ratio of intensity outside to that inside the shield was 1.24. Clay and Van Tijn do not state the change in cosmic-ray intensity in their experiment, but the ratio of the ionization with their shield to that without the shield was 1.7. Since some of this ionization was undoubtedly caused by gamma-radiation from the air, this factor 1.7 represents an upper limit. Assuming that the range of the radioactive radiation is a few centimeters of iron, as would be the case for a gamma-radiation, we should have expected an effect greater than 60 per cent. of the shielded counting rate, i.e., 40 times our probable error. On the other hand, it is conceivable, although there are many theoretical arguments to the contrary, that the radioactive radiation had such an extremely long range that all of the iron in Clay and Van Tijn's experiment contributed appreciably. We should even then have expected the easily detectable increase of 5.4 per cent.

There still remains the possibility that the decaying ionization observed by Clay and Van Tijn was produced by one or more simultaneous particles each of which produced a number of ion pairs large compared with that formed by an electron. Because of the high pressure employed this seems unlikely, and cloud chamber data offer no support to this explanation.

We may express the probable error of the zero effect observed here more concisely. It may be shown that if we have n atoms which may be made radioactive, the initial counting rate which would be observed when these atoms were suddenly placed under a shield is

$$nJE\sigma(1 - e^{-\lambda t})/\lambda t,$$

where J is the change in cosmic-ray intensity, E the efficiency of the counters for recording a disintegration, λ the decay constant of the radioactivity, t the time of observation, and σ the cross section for production of a radioactive atom.

If we assume that the range of the radioactive radiation is greater than 5 cm., we may take $n = 6.6 \times 10^{25}$, $J = 3.7 \times 10^{-3}$ cm.$^{-2}$ sec.$^{-1}$, $E = 10^{-2}$, $t = 2.5$ min., and we may state the result of our experiment as

$$\sigma = 0 \pm 5.4 \times 10^{-23} \times [(1 - e^{-2.5\lambda})/2.5\lambda] \text{ cm.}^2.$$

For a half-life of 8.6 min. the quantity in brackets is 1.06 and approaches unity as λ approaches zero.

The authors wish to express their thanks to Dr. G. L. Locher for the loan of his scale of 64 counter circuit, and to Professor W. F. G. Swann for his helpful discussion of the matters involved herein.

A GRID CONTROLLED IONIZATION GAUGE.*

BY

C. G. MONTGOMERY AND D. D. MONTGOMERY.

There have been described four types of electron current control for ionization gauges.[1] In each type, the entire emission of the filament is accelerated to produce the ionization, and the amount of the emission is maintained constant by controlling the filament current. We wish to describe here another principle of operation which is somewhat simpler. Instead of using a single grid and accelerating the whole emission of the filament, it is possible to employ a gauge with two grids, and accelerate only those electrons which have passed the first grid. The number of such electrons can be regulated by the potential of the first grid, and is then largely independent of the emission of the filament and the filament current. It is then possible to control the potential of the first grid in such a way as to make this independence practically complete.

As an illustration of this method, we have employed a standard type 47 vacuum tube for a gauge. The circuit diagram, with the appropriate constants indicated, is given

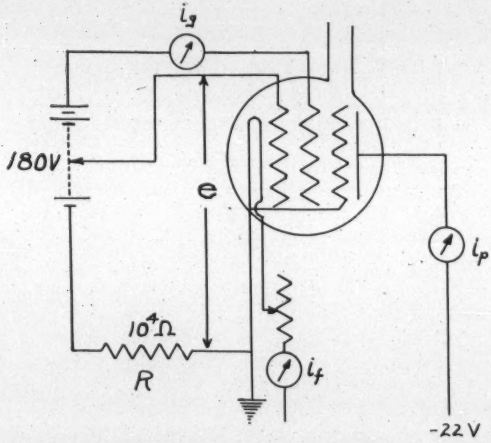
* Reprinted from the *Physical Review*, 9, 58 (1938).

[1] E. K. Jaycox and H. W. Weinhart, *R. S. I.*, 2, 401–411 (1931); W. P. Overbeck and F. A. Meyer, *ibid.*, 5, 287–289 (1934); J. B. Hoag and N. M. Smith, *ibid.*, 7, 497–499 (1936); L. N. Ridenour and C. W. Lampson, *ibid.*, 8, 162–164 (1937).

in Fig. 1. With this arrangement, when the current i_g tends to increase, the potential of the first grid will tend to decrease because of the increased potential drop across the resistance R. This will, in turn, decrease i_g, and the ionizing electron current is thus maintained constant.

To test the performance of this circuit, we varied the emission of the filament by varying the filament current, i_f, and observed i_g. Figure 2 shows two of the characteristic curves obtained in this manner. The change in the emission

FIG. 1.



Circuit diagram of grid controlled ionization gauge.

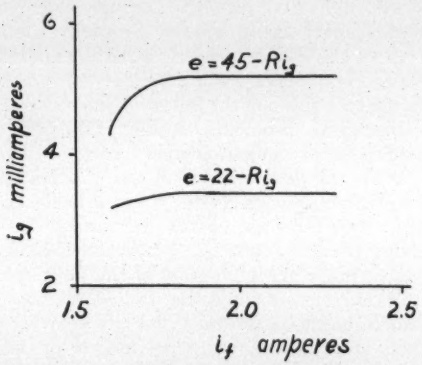
produced by these variations in i_f was, of course, very large, and yet, if i_f was large enough, no appreciable change in i_g was observed. The electron current, when so stabilized, remained at a constant value when the pressure in the gauge was increased, up to the point where a discharge was set up.

The behavior of this type of gauge was checked by comparison with a standard arrangement using a type 45 vacuum tube, and was found to be entirely satisfactory.

The sensitivity, for an electron current of 5 milliamperes, was approximately 6×10^{-6} mm. of mercury per microampere of positive ion current.

This principle of stabilization may be applied, of course, to other types of vacuum tubes used as ionization gauges. We merely give an example of what may be expected from its application. It is possible, of course, to obtain the necessary potentials from a rectified alternating current

FIG. 2.



Characteristic curves showing the independence of the electron current and the emission of the filament.

source, and to heat the filament from a transformer. The authors feel that the simplicity of a grid controlled type of gauge gives it some advantage over the other types now in use. They are also of the opinion that the life and stability of emission of a coated filament are increased by space charge limiting of the current instead of drawing the saturation current, and by avoiding the continuous change of the heating current.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

Seminar on New Methods in Micro Histochemistry.—DR. K. LINDERSTRØM-LANG, who participated in delivering the 34th series of Harvey Lectures for 1938–39, who gave the Edward K. Dunham Lectures at Harvard Medical School for 1939, and who delivered the 1939 annual Biochemical Research Foundation Lecture at the Franklin Institute, on March 20 visited the Laboratories of the Biochemical Research Foundation and conducted a seminar.

The discussion was along the following lines:

Many biological problems require methods sensitive enough to carry out investigation with a very small amount of material. With the development of the Linderstrøm-Lang-Holter micro-technique a successful attempt has been made to satisfy such requirements. Since beginning his investigations, about 10 years ago, Dr. Linderstrøm-Lang and his co-worker have made great progress in the development and refinement of this micro-technique. In general, most of these biological micro-methods are based on the very far reaching refinement of the already existing macro or semi-micro methods, whereby the reactions are followed by titration or are measured by the physico-chemical changes occurring during the reaction.

Biological reactions followed by titration make two basic demands: the exact measurement of very small amounts of liquids, and a micro-burette sensitive enough to measure the minute changes occurring during the reaction. The first requirement is fulfilled by the use of the capillary pipettes, which are emptied by constant pressure, although automatic pipettes have been devised which do not require a constant pressure, the flow of the liquid being regulated by two constrictions. For the actual titration, a special micro-burette is used, which is accurate within 0.02 cmm.

A great improvement in the estimation of ammonia was reported by Dr. Linderstrøm-Lang. Biological reactions con-

nected with volume changes can be measured easily on a micro scale by dilatometric methods. In a vertical glass tube a practically linear specific gravity gradient is produced by mixing kerosene and bromobenzene in varying proportions. If a small drop of aqueous solution, in which no reactions take place, is added at the surface of the liquid in this tube, it will fall at a decreasing rate and finally find an equilibrium position at which the specific gravity of the surrounding medium is equal to its own. If, however, processes take place within the drop causing its volume to decrease or increase and thereby causing its specific gravity to change, the drop will not come to a standstill, but will continue to fall or begin to rise at a rate which, under certain conditions, is a measure of the rate of reaction. This method has been applied to the measurement of peptidase activity and is about 50 times more accurate than the previously described micro-method based on titration.

For the study of respiration or in cases generally where gasometric analysis is used, the principle of the "Cartesian Diver" is applied. The materials to be investigated are placed in a micro "diver" and if for some reason the quantity of gas in the micro-diver decreases or increases, the degree of pressure change will be a measure of the change in the volume of the gas. If, therefore, within the diver, processes take place involving liberation or absorption of gas, the rate of these processes may be estimated quantitatively by measuring, at different times, the pressure under which the diver is in equilibrium at a fixed level. Any variation in the quantity of the gas within the diver may be measured with an accuracy of 0.002 cmm.

An improved freezing-microtome technique for histo-enzymatic experiments was presented by Dr. Linderstrøm-Lang. This improved technique permits the use of the same tissue column for histological studies and for enzymatic investigations, and reduces considerably the histological work required to correlate the enzymatic findings with the histological structure of the investigated tissue.

The applications of the Linderstrøm-Lang-Holter micro-technique cover a wide range. The distributions of various enzymes, pepsin, peptidase, lipase, cholin esterase, urease, have been studied in the gastric mucosa. Similar studies have

been carried out on the distributions of proteolytic enzymes in the rabbit kidney. This technique was successfully applied to the localization of enzymes within a single cell (marine ova, and protozoa). The same methods have been found very useful in studying the distributions of amylase and vitamin C in different layers of barley grain. Similar investigations were made on the distributions of peptidase, proteinase and lipase in dormant and germinating wheat seeds. The vitamin C studies were extended to the localization of this vitamin in the adrenal gland. The results already obtained with the Linderstrøm-Lang-Holter micro-technique indicate the great usefulness of these methods and we may be assured of further developments in the future.

(Reported by L. WEIL.)

Some Effects of Pyrophosphate on the Metabolism of Tissues.—MARGARET ELIZABETH GREIG AND MURIEL PLATT MUNRO. (*Biochemical Journal*, **33**: 143, Feb. 1939.) The succinoxidase system has been shown by various investigators to play an important role in the respiration of most normal tissues, but in cancer tissue it is present only in small amounts or is completely lacking. Dixon has shown that pyrophosphate is a specific inhibitor for succinoxidase. The effect of pyrophosphate on the metabolism of various tissues was determined in order to find out whether succinoxidase was responsible for the bulk of the respiration of these tissues. It seemed possible that pyrophosphate also affected metabolism since it is a normal constituent of the cell, forming, in combination with vitamin B_1, co-carboxylase, the co-enzyme necessary for oxidation of pyruvate which is an intermediate in carbohydrate and protein metabolism.

Dixon-Keilin differential manometers were used in studying tissue metabolism. The advantages of this technique were that oxygen uptake, R.Q. and glycolysis could all be determined on the one sample of tissue.

The effect of pyrophosphate on tissue slices varies with the concentration of pyrophosphate, the tissue used and the substrate being metabolized. With rat tumor (Walker 256), dilute pyrophosphate in the presence of glucose increases the respiration slightly without affecting glycolysis. A more

concentrated solution in the presence of glucose inhibits respiration 35 per cent. In both cases the R.Q. is considerably decreased. In the absence of glucose, pyrophosphate has practically no effect on respiration and glycolysis. It also has no effect on lactate metabolism. Elliott and co-workers found an extremely low succinoxidase content in Walker 256 tumor; succinate apparently is not involved in respiration, or it may be that succinoxidase is a limiting factor. The definite effects of pyrophosphate, particularly on the R.Q., show that it does penetrate cells to a certain extent. If we can assume that it penetrates considerably, we must expect succinoxidase inhibition; the absence of more marked effects on respiration then means that succinate is not an essential intermediate of respiration in this tissue.

With testis, which is also low in succinoxidase activity, pyrophosphate inhibits O_2 uptake somewhat both in the presence and absence of glucose, indicating that the succinate system is probably important to a certain extent.

Pyrophosphate has little effect on the normal respiration of liver slices, but in the presence of glucose respiration is inhibited 31 per cent. and acid formation is increased. With added lactate, O_2 uptake is inhibited 24 per cent. and acid removal is practically completely inhibited. This indicates that the metabolism of liver, especially with added lactate, is, like that of testis, at least in part dependent on the succinoxidase system.

With brain slices pyrophosphate has no effect on the respiration in the presence of glucose or on the metabolism of lactate.

With kidney the effects are different from those found with the above tissues. In the absence of glucose pyrophosphate causes a slight inhibition in O_2 uptake and some accumulation of acid; in the presence of glucose there is increased respiration and glycolysis. These results indicate that there may be an alternative path of oxidation to that proceeding by way of succinate, or it may be that succinoxidase is not completely inhibited and perhaps other systems, such as the malic and lactic systems, are accelerated so that the net result is increased oxidation in the presence of glucose. With added succinate, pyrophosphate inhibits the removal of acid groups by 60

per cent. and O_2 uptake about 12 per cent., but respiration is still greater than it is in the absence of substrate or inhibitor, indicating that some succinate is still being oxidized. This is to be expected in view of the extremely high succinoxidase content of kidney. In the presence of pyruvate, pyrophosphate inhibits removal of acid groups about 60 per cent., i.e. about the same as for succinate, but the O_2 uptake remains the same as without inhibitor. Pyrophosphate decreases acid disappearance in the presence of malate about 78 per cent. and respiration is decreased to about the same extent as with added succinate, although it is still higher than in the absence of substrate. With added lactate, pyrophosphate has no effect on O_2 uptake but decreases acid removal 65 per cent. These results indicate the participation of the succinoxidase system in the complete oxidation of substrates by kidney.

Ox retina differs from the other tissues studied in its reaction to pyrophosphate. Like testis it has a low succinoxidase content but added pyrophosphate, instead of inhibiting respiration, causes a large increase in O_2 uptake and a small increase in glycolysis in the presence of glucose. Without added substrate there is usually some increase in respiration. In all cases pyrophosphate raises the R.Q. With lactate as substrate pyrophosphate also causes a considerable increase in O_2 uptake and a small increase in acid disappearance. It will be shown in a forthcoming paper that the rate of succinate oxidation by ox retina is not great enough for it to be a link in the chain of reactions for the oxidation of lactate. That pyrophosphate does not inhibit but indeed accelerates lactate and acid removal is further evidence that this reaction does not go through succinate.

BOOK REVIEWS.

CHARCOT OF THE ANTARCTIC, by Marthe Oulie. 235 pages, illustrations, plates, 15 × 23 cms. New York, E. P. Dutton and Company Inc., 1939. Price $3.50.

The name of Charcot is known by many of different callings. In medicine the name stands out with other great leaders. Dr. Charcot's work in his chosen field cannot be forgotten, for his skill, knowledge, and achievements are constant reminders that his was a will to succeed for the sake of humanity and the glory of France. Jean Charcot, the doctor's son, likewise had the attributes which made for similar success although in other fields of endeavor.

This book is a story of the life of Charcot, the younger. Written in the form of a narrative, it sketches the life of Jean Charcot from birth to death. It tells of his early schooling, some childhood pranks which undoubtedly led to channels of endeavor in later life, his formal education in medicine, his great liking for the sea, his preparation for and subsequent trips to the Antarctic, activities during the World War, and his work in the Arctic. A vivid picture is painted of this great man under favorable and unfavorable circumstances. It is interesting to read of the tremendous driving power exhibited by this man in overcoming difficulties that lay in the path of his most desired accomplishments. Similarly, his personality is well portrayed.

Charcot was an explorer and scientist. He never aimed for or reached the South Pole, but his work of mapping, discovering, and the obtaining of scientific data in the Antarctic was invaluable. It was done under very trying conditions which required leadership of the highest calibre, backed up with bravery, courage, and knowledge. The account of all this is intimate, so intimate in fact that it gives a warmth of feeling and friendship, capable of being made only by one who was very close to Jean Charcot and quite familiar with the sea. The book is written in a style showing much skill in the art of literary presentation. The illustrations scattered throughout the work are exceptional and cannot fail to draw interest. Emphasis is laid primarily on Charcot's Antarctic and Arctic explorations, with his home life and other activities to reinforce the illustration of his personality, a close second. In comparison, much less is said of Charcot as a U-boat commander during the World War. There seems to be no reason for this, but it does create in the mind of the reader a desire to know more of this phase.

The book has cultural value to those unfamiliar with the regions of the world of which it speaks, it is informative as a biography, and makes easy, interesting, and popular reading.

R. H. OPPERMANN.

STEAM CONQUERS THE ATLANTIC, by David Budlong Tyler. 425 pages, illustrations, plates, 16 × 24 cms. New York, D. Appleton-Century Company, 1939. Price $5.00.

There is probably no industry which has a greater appeal in its romance, than the steamship. It couples the lore of the sea with the fascination of the machine,

the combination if properly handled, furnishing exciting, entertaining, and informative reading. There has been little written of the complete story on the conquering of the sail by steam in the Atlantic, which this book undertakes to do The need for such an account is obvious, but to meet the need satisfactorily a history must first of all be based on facts.

The author of this book apparently realized this, for the work is the result of an exhaustive search which itself must have taken a great deal of time and patience. Emphasis should be laid on patience because in the early records particularly, there were conflicting and contradictory statements which possibly could have been untangled to the satisfaction of the author and so written. The first feature noticeable in the beginning of the book is that no such thing was attempted. The facts are pieced together and laid down for what they are worth, giving an impression of confidence in the author which lasts throughout the book.

The picture of steam vs. sail on the Atlantic is presented in a smooth reading style in as much of a chronological order as such a theme would permit. Deviations are made, of course, but not to the extent that would cause interference. The story begins with the border-line of the use of steam in ships traveling in inland waterways, and proceeds to show the use of steam to supplement the sail on the ocean, which in due time was reversed so that the sail supplemented steam. The evolution of the steamship from the sail boat is strikingly illustrated, as well as the reasons for the change, as they became known. It is shown that speed alone was not enough to defeat the sailing ship. The early steamer was so costly to build and operate that it had to charge rates which only express goods and first class passengers could pay. Real competition only developed when reduced costs, increased capacity, and faster schedules made it possible to reduce rates. Increasing competition brought efforts to make steamship travel more comfortable Gradually the class of passenger and goods carried by steamers became wider. until they included from first class to emigrants and bulky freights. The reader is shown the details of this contest which include glimpses of personalities that played their part, pioneering vessels of a new era in travel, risks and tragedies, and financial as well as business enterprise. All are woven together into a story that is fascinating and inspiring. The book has value as a means of culture. It can be used as a reference work by utilizing its comprehensive index.

R. H. OPPERMANN.

A SHORT HISTORY OF THE STEAM ENGINE, by H. W. Dickinson. 255 pages, plates, illustrations, 16 × 25 cms. New York, The Macmillan Company. Price $3.50.

When reference is made to the history of the steam engine, James Watt is often mentioned as the inventor of the machine. Under this assumption then, this book would merely begin with Watt's work and record development from that time. But as all careful and inquisitive observers know, invention and more-so development are rarely independent of work or knowledge existing previously. This book does not begin with the invention of James Watt nor does it credit James Watt with being the inventor of the steam engine.

The author has tried to combine the occasions that arose which demanded a more efficient power producing device, with some of the basic essentials of the

steam engine, to show how the steam engine, over a long period, took form. For instance, he goes back to 1606 to Porta's scheme for the generation and use of steam. Again, along another line reference is made to work with pumps, and atmospheric pressure. The work of raising water is an occasion cited where need existed for a power machine. As the story goes on, the various essentials are drawn together with the engine as a result.

Up to 1765 the function of working parts were quite well understood. The book explains about Papin and his piston in a cylinder in which he boiled water, and Newcomen and his separate steam generator. On this date James Watt made his invention of condensing steam in a separate cylinder. Other of his inventions followed. Watt is given credit for the inauguration of a new era, almost amounting to a rebirth of the engine. In view of this, the error of crediting Watt with the invention of the engine is excusable. The author puts this very nicely, giving Watt due recognition.

Developments in subsequent periods are related including that between 1801–50 on low-pressure and high-pressure engines and 1851 to the present day. The same is covered with regard to boilers. The latter part of the book is devoted to turbines and is similarly treated from the time of Hero in Alexandria. Because the steam engine is a broad subject covering a number of related or borderline fields of knowledge, as well as classes of equipment and specialized uses, the author has cleverly defined limits of all to the stationary engine as it is known today. In other words the steam locomotive or marine engine is only included in-so-far as they were an outgrowth of the main subject. They are dropped when the elements became separated due to specialization.

The book contains many interesting illustrations. The subject index provides for its use as a reference. It is an authoritative account of a machine that is basic in engineering.

R. H. OPPERMANN.

PHOTOCHEMISTRY AND THE MECHANISM OF CHEMICAL REACTIONS, by Gerhard K. Rollefson and Milton Burton. 445 pages, illustrations, tables, 16 × 23 cms. New York, Prentice-Hall, Inc., 1939. Price $5.75.

Photochemistry today is looked upon as a tool for the study of the detailed mechanisms of reactions. The development of photochemistry to this point has occurred only recently. It started when Bohr, in connection with his theory of atomic structure, advanced the idea that the frequency of light absorbed or emitted by an atom or molecule is determined solely by the energies of the initial and final states of the system. The result was the application of the quantum theory to spectra.

The aim of the authors, in this book, is to acquaint the specialist in photochemistry with progress in associated problems, and at the same time to present to others an understanding of the background and possibilities of the subject. With these broad aims laid down it is interesting to see how the book is constructed and carried through. At the outset, in order to gain the latter part of the above aim, fundamental concepts are considered with the quantum theory as applied in the theory of spectra, the interaction of light with atoms and molecules and the properties of the activated states produced, and a brief review of the basic principles of chemical kinetics. This coverage is by no means complete, in fact, it is a

carefully selected portion of the fields, judged to be sufficient for basic information on photochemistry.

There are ten chapters following this, devoted to detailed experimental and theoretical aspects of the principal subjects in the study of which photochemistry has proved a valuable tool. Photodecomposition, or photolysis is the first class of photochemical reaction considered. This is in the solid state, which is followed by the vapor state and sometime later the liquid state. Then there is a chapter on molecular arrangements where first, space is given to reactions which are apparently simple but shown that they may not be unimolecular, and next the essential mechanism of photosensitization. In later chapters there is discussed chain reactions, polymerization, and heterogeneous reactions under which are included the photochemistry of the white pigments, photography, and photosynthesis.

The book is well composed; contains drawings, curves, and tabular data where necessary; and is appended by a comprehensive subject index. It accomplishes the purposes set forth.

R. H. OPPERMANN.

HIGH-FREQUENCY ALTERNATING CURRENTS, by Knox McIlwain and J. G. Brainerd. Second Edition, 530 pages, illustrations, 16 × 24 cms. New York, John Wiley & Sons, Inc., 1939. Price $6.00.

The necessity for considering the electric circuit from an entirely different viewpoint when dealing with high frequency is well recognized by engineers in the commercial power field. Such factors as skin effect, inductance, capacity, and even resistance take on new and important meanings. Heretofore, high frequency was a field definitely separated from power, into principally communications, but recent years have seen the dividing space constantly narrowing. Today, the education of the electrical engineer, must be extended to include a knowledge of high frequency circuits and apparatus pertaining thereto.

High Frequency Alternating Currents is a text designed for use in college courses. It is mathematical in nature, requiring prerequisites of some calculus and elementary theory of alternating currents. The coverage gives a well rounded knowledge which can be applied to the analysis of wire and wireless communication circuits. The underlying theme is the conversion of sound energy in all its forms into electrical energy of proper type, the radiation of this energy into space, the reception of it, and conversion back to its original form. The treatment begins with that part of the characteristics of sound which has bearing on the subject in general. A brief review of this is given before the theory of high frequency of alternating currents is laid out in an elementary way. Considerable space is given to the mathematical treatment of the vacuum tube and its associated circuits. In like manner, amplification, modulation, and detection are each separately treated. Under the heading of the production of high frequency currents, condenser discharge is discussed at some length; the spark gap oscillator, mechanical oscillators, alternators and arcs, more briefly; and vacuum tube oscillators to a more detailed extent. The electric wave filter is next described with a quite thorough coverage on its characteristics and types.

Probably the most vulnerable part of power engineering for the introduction of the theory of high frequency currents is on transmission lines. The chapter on this is exceptionally well done. It should have equal appeal to the communication

and power engineer. The latter part of the book contains divisions on electromagnetic waves, reflection and refraction, and finally electromechanical systems.

The book is complete with curves and drawings where such are helpful, appendicies with useful information, and a subject index. The order in which the topics are discussed is logical although somewhat unusual, allowing for flexibility in study and reference. The subject matter is up-to-date in every respect and is presented from a modern viewpoint.

R. H. OPPERMANN.

PROTECTIVE COATINGS FOR METALS, by R. M. Burns and A. E. Schuh. 407 pages, illustrations, 16 × 24 cms. New York, Reinhold Publishing Corporation, 1939. Price $6.50.

Many millions of dollars are lost each year due to corrosion of metallic structures. Recognition of this fact has resulted in measures which are exceedingly effective in checking corrosion and so extending the useful life of metals and metallic products. Protective coatings seek control of corrosion by interposing a protective film between the metal and its surroundings. This method has seen considerable development in the past decade which has been the result of research in the mechanism of corrosion as well as in the properties of the film itself.

In 1927 H. S. Rawdon's Protective Metallic Coatings appeared in the present monograph series. The present book is a revision of that by Rawdon but in addition it has been expanded to include protective coatings of all types including paints. The opening chapter gives a brief discussion of the principles of corrosion which is the foundation for examining the performance of coatings of various kinds covered in later chapters. Also briefly covered is that very important subject of surface preparation for the application of coatings. With this background, types of metallic coatings and the methods of application are taken up, followed by the kinds of coating. Considerable space is devoted to zinc coatings—by the hot-dipping process, electroplating and cementation—and much practical information is given on the protective value of this type of coating in the way of comparative life of different types of finishes, and in different atmospheres. Cadmium coatings and their protective value preceed treatments on other coatings such as tin, nickel and chromium, copper, lead, and aluminum. Coatings of noble and rare metals are given special attention. Likewise methods of testing metallic coatings to determine their quality and the determination of the rate of corrosion.

The application of paints for the protection of metals against corrosion occupies the latter portion of the book, a most important topic in view of recent findings, the interpretation of which are not as yet complete. This topic begins with the mechanism of film formation and proceeds through the durability and evaluation of paints, consideration of some of the more practical phases of the subject such as the painting of large outdoor steel structures and the protection of underground pipe structures, and finally a chapter on miscellaneous coatings which includes electrolytic oxide coatings on aluminum, surface conversion, slushing compounds etc.

The book is well illustrated and is the result of a compilation and abstracting of an enormous number of widely scattered papers to give an up-to-date summary of the state of the art. There are author and subject indexes. It is a tool for reference and a means of practical help in combating corrosion.

R. H. OPPERMANN.

THE APPLICATION OF TENSORS TO THE ANALYSIS OF ROTATING ELECTRICAL MACHINERY. Parts I–XVI, Elementary Engineering Treatment, by Gabriel Kron. 187 pages, illustrations, 20 × 27 cms. Schenectady, General Electric Review, 1938. Price $4.50.

This is a republication in book form of 16 parts of a serial on this subject which appeared in the General Electric Review recently and which was the forerunner of a text on tensorial analysis of networks, reviewed in these columns. As the title of the book at hand indicates, it is devoted specifically to rotating electrical machinery. There is revealed here a generalized theory by which the complete transient and steady-state performance of any particular type of machine or group of machines can be derived by substituting the particular brush, collector rings, and circuit interconnections in a set of completely general tensor equations. In so doing the physics of the problem can be seen from different angles. The treatment first lays down the rules and symbolism of tensors and then proceeds to show their application in machines of stationary and moving axes, interconnection, machines under acceleration, and oscillations. The procedure through applications is interrupted at points to add further necessary material on forms of equations, but the sequence is logical and constructive.

While the subject indicates a mathematical flavor, it, as here presented is in a form not too strictly mathematical but that the engineer should find it a useful tool and time saver in many analyses now requiring an enormous amount of work and drudgery. The future, it may be predicted, will reveal a more general use of tensors in this field.

R. H. OPPERMANN.

GREEK MATHEMATICS AND ASTRONOMY, by Sir Thomas Little Heath. 18 pages, 17 × 25 cms. New York, *Scripta Mathematica*, 1938. Price 25 cents.

This very interesting little pamphlet containing an address delivered at Cambridge, England, is a reprint from *Scripta Mathematica*, Vol. 5, No. 4. The author outlines the subject beginning with Thales in the sixth century B.C. in geometry, astronomy, arithmetic and algebra. Sharp focus is centered here but considerable background is furnished in the nature of the condition of knowledge of these subjects previous to and at this time, as in Egypt and Babylon. The work of the Greeks in the pioneering into these fields is admirably described which makes interesting and informative reading.

R. H. OPPERMANN.

MODERN MAGNETISM, by L. F. Bates. 340 pages, illustrations, 15 × 22 cms. New York, Cambridge University Press, 1939. Price $4.50.

The industrial applications of magnetism and magnetic materials requires a thorough knowledge of fundamentals of the subject. Its place in the study of physics is often one not best suited for a part of prime importance and for some reason or other its presentation is not such as to facilitate complete understanding, according to the author of this book. Certainly the phenomena has been the cause of many inquiries into its theory and many valuable experiments which have been recorded in a somewhat scattered manner. With this in mind the purpose of the book has been set to present an account of modern knowledge for students and others interested.

The contents of the book generally indicate a quite thorough discussion. Fundamental conceptions in magnetism as treated give the theory of diamagnetism, the Langevin function and the vector atom model. This section shows the calculation of susceptibility as based upon the conception of a paramagnetic gas in which all the particles are uninfluenced by the electric or magnetic fields of their neighbors. Later, in discussing the phenomenon of ferromagnetism, the new theory of it is recognized as being attributed to an interchange interaction between electron spins and that the orbital momenta may be quenched and only the spins left free. After this the means of production and measurement of magnetic fields is taken up.

The experimental methods and technique for the determination of the magnetic susceptibilities of isotropic substances is indeed a noteworthy treatment. The subject matter, covering polycrystalline solids, assumes that the direction of magnetism always coincides with the direction of the applied field. Cases are cited, following, of single crystals of a weakly magnetic substance placed in a magnetic field where the general direction of magnetisation does not coincide but where this induced magnetisation is not sufficient to produce marked distortion of the applied field. Consideration is then given as to the information that can be obtained from the method of molecular rays concerning the magnetic properties of the nucleus.

Under the heading of Gyromagnetic Effects the properties of the gyroscope are explained before outlining the experiments which were the outgrowth of Richardson's on his recognition of the gyrostatic properties of the electron. Magnetic saturation and equation of state, energy changes associated with reversable magnetisation and magnetostriction or changes in dimensions of ferromagnetics when exposed to a magnetic field are topics which complete the book. There is a subject and a name index in the back.

The work is the result of an exhaustive study of widely scattered literature, coupled with an intimate knowledge of the subject and expert ability in presentation. Much information is made available in compact form which should aid materially those who do not have the facilities or time to search.

R. H. OPPERMANN.

CHEMICAL KINETICS, by Farrington Daniels. 273 pages, illustrations, 16 × 24 cms. Ithaca, Cornell University Press, 1938. Price $3.25.

This book is one of those based upon lectures delivered at Cornell University under the George Fisher Baker Non-Resident Lectureship in Chemistry. In this, as in other publications of the same series, the author is expected to present the most recent advancements and the results of his own investigations in the field, and to devote most of the discussion to his own work.

The book begins with a general treatment of the principles of reaction kinetics. Specific reaction rate and energy of activation receive some attention, as also does the Arrhenius equation for the effect of temperature on a chemical reaction.

The various theories of unimolecular reactions are the subject of extended discussion, copiously illustrated by examples from the author's extensive work. Proceeding to gas phase reactions, in which the work of Professor Daniels has been particularly rich, the decomposition of nitrogen pentoxide and ethyl bromide serve as definite examples. This chapter gives an interesting discussion of the

glass diaphragms so necessary in pressure measurements in those systems where mercury may not contact the reactants or products directly.

Kinetics of Reactions in Solution forms the subject of Chapter V, in which the decomposition of nitrogen pentoxide, chloroacetate ion and ammonium amalgam are cited as examples. In other chapters the author carries his study into the field of photochemistry, electrical activation and infra red spectroscopy. The book ends with two chapters deserving of particular mention—Theoretical Calculation of Activation Energies and Isotopic Tracers.

Chemical Kinetics is well written, as would be expected from Professor Daniels' pen, and is one of the most interesting books available in the field of reaction kinetics. It cannot be recommended as covering the field completely, but that is not the object of the George Fisher Baker Lectureship.

As one of the major omissions might be mentioned the reaction between solids and gases. However, as this subject is so little understood, and is covered in only a few foreign publications, perhaps the omission can be excused on the grounds of prematurity.

A few slight errors have been noted by the reviewer, as follows:

p. 24, line 21, "w and dw" should read "w and $w + dw$,"
p. 54, line 10, "$k_2c_{R1}c_{R2}$" should read "$k_2c_{R1}c_{M1}$."

No errors of a serious nature have been observed.

The reviewer has read Chemical Kinetics with pleasure, and does not hesitate to recommend it. Professor Daniels is to be complimented on an excellent piece of work.

GEORGE S. GARDNER.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 637, Determination of Boundary-Layer Transition on Three Symmetrical Airfoils in the N. A. C. A. Full-Scale Wind Tunnel, by Abe Silverstein and John V. Becker. 15 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1939. Price 10 cents.

For the purpose of studying the transition from laminar to turbulent flow, boundary-layer measurements were made in the N. A. C. A. full-scale wind tunnel on three symmetrical air-foils of N. A. C. A. 0009, 0012, and 0018 sections. The effects of variations in lift coefficient, Reynolds Number, and air-foil thickness on transition were investigated. Air speed in the boundary layer was measured by total-head tubes and by hot wires; a comparison of transition as indicated by the two techniques was obtained.

The results indicate no unique value of Reynolds Number for the transition, whether the Reynolds Number is based upon the distance along the chord or upon the thickness of the boundary layer at the transition point. In general, the transition is not abrupt and occurs in a region that varies in length as a function of the test conditions. With increasing lift, the transition on the upper surface moves toward the forward stagnation point; whereas, on the lower surface, the transition progresses in the opposite direction. This effect is most marked for the thin airfoils. The total-head tubes and hot wires indicate essentially the same point of transition. Profile-drag results are given and a correlation of the drag and the transition measurements is attempted.

Report No. 646, The Compressibility Burble and the Effect of Compressibility on Pressures and Forces Acting on an Airfoil, by John Stack, W. F. Lindsey, and Robert E. Littell. 24 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1938. Price 15 cents.

Simultaneous air-flow photographs and pressure-distribution measurements were made of the N. A. C. A. 4412 airfoil at high speeds to determine the physical nature of the compressibility burble. The tests were conducted in the N. A. C. A. 24-inch high-speed wind tunnel. The flow photographs were obtained by the schlieren method and the pressures were simultaneously measured for 54 stations on the 5-inch-chord airfoil by means of a multiple-tube manometer. Following the general program, a few measurements of total-pressure loss in the wake of the airfoil at high speeds were made to illustrate the magnitude of the losses involved and the extent of the disturbed region; and, finally, in order to relate this work to earlier force-test data, a force test of a 5-inch-chord N. A. C. A. 4412 airfoil was made.

The data presented include the results of pressure-distribution measurements and force tests for three low angles of attack for a speed range extending from one-tenth the speed of sound to speeds in excess of the critical values at which a breakdown of the flow, or compressibility burble, occurs.

The results show the general nature of the phenomenon known as the compressibility burble. The source of the increased drag is shown to be a compression shock that occurs on the airfoil as its speed approaches the speed of sound. Finally, it is indicated that considerable experimentation is needed in order to understand the phenomenon completely.

Report No. 647, Tests of N. A. C. A. 0009, 0012, and 0018 Airfoils in the Full-Scale Tunnel, by Harry J. Goett and W. Kenneth Bullivant. 10 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1938. Price 10 cents.

An investigation was conducted in the N. A. C. A. full-scale wind tunnel to determine the aerodynamic characteristics of the N. A. C. A. 0009, 0012, and 0018 airfoils, with the ultimate purpose of providing data to be used as a basis for comparison with other wind-tunnel data, mainly in the study of scale and turbulence effects. Three symmetrical 6- by 36-foot rectangular airfoils were used. The Reynolds Number range for minimum drag was from 1,800,000 to 7,000,000 and for maximum lift, from 1,700,000 to 4,500,000. The effect of rounded tips was determined for each of the airfoils. Tests were also made of the N.A.C.A. 0012 airfoil equipped with a 0.20c full-span split flap hinged at 0.80c. Tuft surveys were included to show the progressive breakdown of flow near maximum lift.

Momentum surveys were made in conjunction with force measurements at zero lift as an aid in converting force-test data to section coefficients.

Report No. 649, The "Pack" Method for Compressive Tests of Thin Specimens of Materials Used in Thin-Wall Structures, by C. S. Aitchison and L. B. Tuckerman. 12 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1939. Price 10 cents.

The strength of modern lightweight thin-wall structures is generally limited by the strength of the compression members. An adequate design of these

members requires a knowledge of the compressive stress-strain graph of the thin-wall material. The "pack" method was developed at the National Bureau of Standards with the support of the National Advisory Committee for Aeronautics to make possible a determination of compressive stress-strain graphs for such material.

In the "pack" test an odd number of specimens are assembled into a relatively stable pack, like a "pack of cards." Additional lateral stability is obtained from lateral supports between the external sheet faces of the pack and outside reactions. Studies have been made of the reproducibility of the test results by testing packs taken from sheets of aluminum alloy 17ST and steel. The largest spread in yield strength was about 2 per cent. Tests were also made to determine whether the results from packs were like those obtained from compact solid specimens. The results indicated that the method of transverse support had no appreciable effect on the yield strength. The largest difference between a pack and a solid specimen was 1.60 per cent. Experience gathered in developing the test emphasized the fact that, while the method seemed to furnish results within the same order of accuracy as was usually obtained from other mechanical tests, such as the tensile test, it must be simplified before it can be used economically for inspection testing. The test seems adequate, however, for many problems in structural research.

Report No. 651, Downwash and Wake Behind Plain and Flapped Airfoils, by Abe Silverstein, S. Katzoff, and W. Kenneth Bullivant. 28 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1939. Price 15 cents.

Extensive experimental measurements have been made of the downwash angles and the wake characteristics behind airfoils with and without flaps and the data have been analyzed and correlated with the theory. A detailed study was made of the errors involved in applying lifting-line theory, such as the effects of a finite wing chord, the rolling-up of the trailing vortex sheet, and the wake.

The downwash angles, as computed from the theoretical span load distribution by means of the Biot-Savart equation, were found to be in satisfactory agreement with the experimental results. The rolling-up of the trailing vortex sheet may be neglected, but the vertical displacement of the vortex sheet requires consideration.

By the use of a theoretical treatment indicated by Prandtl, it has been possible to generalize the available experimental results so that predictions can be made of the important wake parameters in terms of the distance behind the airfoil trailing edge and the profile-drag coefficient.

The method of application of the theory to design and the satisfactory agreement between predicted and experimental results when applied to an airplane are demonstrated.

Report No. 653, A Study of Air Flow in an Engine Cylinder, by Dana W. Lee. 13 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1939. Price 10 cents.

A 4-stroke-cycle test engine was equipped with a glass cylinder and the air movements within it were studied while the engine was being motored. Different

types of air flow were produced by using shrouded intake valves in various arrangements and by altering the shape of the intake-air passage in the cylinder head. The air movements were made visible by mixing feathers with the entering air, and high-speed motion pictures were taken of them so that the air currents might be studied in detail and their velocities measured. Motion pictures were also taken of gasoline sprays injected into the cylinder on the intake stroke.

The photographs showed that: A wide variety of induced air movements could be created in the cylinder; the movements always persisted through the compression stroke; and the only type of movement that persisted until the end of the cycle was rotation about the cylinder axis. The velocities of the air currents were approximately proportional to the engine speed and had about the same value whether the flow was orderly or turbulent. Orderly air movements greatly aided the distribution of the sprays about the cylinder.

PUBLICATIONS RECEIVED.

The Fundamentals of Electro-Magnetism, by E. Geoffrey Cullwick. 352 pages, illustrations, 14 × 23 cms. New York, The Macmillan Company, 1939. Price $4.50.

Mecanique Statistique Quantique, by Francis Perrin. 224 pages, 17 × 25 cms. Paris, Gauthier-Villars, 1939. Price 100 fr.

Proceedings of the Sixth Summer Conference on Spectroscopy and Its Application, held at the Massachusetts Institute of Technology, Cambridge, Massachusetts, July 18–20, 1938. 172 pages, illustrations, 19 × 26 cms. New York, John Wiley & Sons, Inc., 1939. Price $3.00.

Applied Acoustics, by Harry F. Olson and Frank Massa. Second Edition, 494 pages, illustrations, 15 × 22 cms. Philadelphia, P. Blakiston's Son & Co., Inc. 1939. Price $5.50.

Das Chemische Feuerlöschwesen, von Dr. Oskar Kausch. 283 pages, illustrations, 15 × 23 cms. Leipzig, S. Hirzel, 1939. Price 18.50 R.M.

Hormaon und Baryon, Eine Attraktions- und Gravitations-Hypotheses, von Hans Emil Hermes. I. Teil, 89 pages, 15 × 22 cms. Salzburg, Anton Pustet, 1938.

Bericht über die 3, Internationale Tagung der Leiter grubensicherheitlicher Versuchsanstalten in Dortmund, vom 23, bis 28, September 1935. 312 pages, illustrations, Gelsenkirchen, Carl Bertenburg, 1939.

U. S. Coast and Geodetic Survey, Field Engineers Bulletin Number 12, December 1938. 253 pages, illustrations, plates, 20 × 27 cms. Washington.

Electric Power Statistics, 1938. 54 pages, illustrations, 20 × 27 cms. Washington, Federal Power Commission, 1939.

Illinois, State Water Survey, Supplement I to Bulletin 21. 311 pages, 15 × 23 cms. Urbana, State Water Survey Division, 1938.

National Advisory Committee for Aeronautics. Technical Notes: No. 699, Tests of an N. A. C. A. 23012 Airfoil with a Slotted Deflector Flap, by R. O. House. 8 pages, illustrations. No. 700, Theory of Automatic Control of Airplanes, by Herbert K. Weiss. 48 pages, illustrations. No. 701, Intermittent-

Flow Coefficients of a Poppet Valve, by C. D. Waldron. 13 pages, illustrations No. 702, Wind-Tunnel Tests of Several Forms of Fixed Wing Slot in Combination with a Slotted Flap on an N. A. C. A. 23012 Airfoil. 26 pages, illustrations. No. 703, Wind-Tunnel Investigation of Effect of Yaw on Lateral-Stability Characteristics I—Four N. A. C. A. 23012 Wings of Various Plan Forms with and without Dihedral, by M. J. Bamber and R. O. House. 17 pages, illustrations. No. 704, Some Notes on the Numerical Solution of Shear-Lag and Mathematically Related Problems, by Paul Kuhn. 18 pages, illustrations. Six pamphlets, 20 × 26 cms. Washington, Committee, 1939.

Bell Telephone System, Monographs: B-1115, Composition and Colloidal Properties of Balata Latex, by A. R. Kemp. 16 pages, illustrations. B-1116, Molecular Rotation and Dielectric Behavior of Condensed Phases, by Addison H. White. 8 pages, illustrations. B-1118, An Improved Three-Channel Carrier Telephone System, by J. T. O'Leary, E. C. Blessing and J. W. Beyer. 27 pages, illustrations. B-1119, Crossbar Dial Telephone Switching System, by F. J. Scudder and J. N. Reynolds. 43 pages, illustrations. B-1120, The Impact Testing of Plastics, by Robert Burns and Walter W. Werring. 14 pages, illustrations. B-1124, A Terrain Clearance Indicator, by Lloyd Espenschied and R. C. Newhouse. 13 pages, illustrations. B-1126, A Twelve-Channel Carrier Telephone System for Open-Wire Lines, by B. W. Kendall and H. A. Affel. 24 pages, illustrations. B-1128, Transcontinental Telephone Lines, by J. J. Pilliod. 11 pages, illustrations. B-1129, Recent Developments in the Measurement of Telegraph Transmission, by R. B. Shanck, F. A. Cowan and S. I. Cory. 47 pages, illustrations. Nine pamphlets, 15 × 23 cms. New York, Bell Laboratories, 1939.

CURRENT TOPICS.

An Unusual Metal.—Colalloy, a non-ferrous silvery metal, two-thirds lighter than steel and most common metals, unusually resistant to corrosion, outstanding in electrical and thermal conductivity, strong, workable, beautiful, and low in cost, is in production. This metal is made in all the forms, shapes, gauges and range of sizes that are available in most common metals. Hundreds of dies and tools are on hand to make commonly used items such as pans, trays, trucks, containers, etc. The properties of colalloy are highly desirable. Its salts are colorless, odorless, non-toxic, tasteless, and non-contaminating even to the most delicate foods and finest materials. Colalloy cannot rust. For its physical properties, colalloy has a range of hardnesses, tensile strengths, working factors and other properties, which make it an all purpose metal. Accordingly it lends itself to common fabrication practices with standard tools and equipment. The natural appearance of colalloy is silvery, but it is also available in Chromaloy, Satin and other surface effects, with high mirror-like chrome, or smooth non-reflective silvery appearance. The metal is manufactured by the Colonial Alloys Company of Philadelphia, Pa.

R. H. O.

Air Hygiene.—More than 200 executives from 101 industrial concerns attended the third annual fall meeting of Air Hygiene Foundation held at Mellon Institute, Pittsburgh, recently. The executives, from the four corners of the country, heard reports on latest advances in protecting the health of industrial workmen who lose an estimated 200 million working days yearly because of illness. A dozen state and federal agencies sent special representatives to the meeting. Reports covered engineering and medical developments during the past year toward employee health improvement, state codes governing health hazards, legal and economic trends. Prof. Philip Drinker of Harvard, Chairman of the Foundation's Preventive Engineering Committee, stated that there is great need for a critical survey of design and operation of existing exhaust systems in industry. Such a study would bring out fundamental requirements of design, particularly with respect to air velocities through hoods, transporting velocities, etc. Past experience needs to be studied critically in order to provide a basis for future design. T. F. Hatch,

New York State Division of Industrial Hygiene and a member of the Preventive Engineering Committee, discussed "State Codes for Control of Industrial Health." He said "Code requirements of a state never quite catch up with the standards established in the best industrial establishments. It is estimated that less than 10 per cent. of the progress in accident prevention in industry can be credited to mechanical contrivances such as you would put in a code, and that better than 90 per cent. is the result of intelligent management." Dr. Leroy U. Gardner, Director, the Saranac (N. Y.) Laboratory, reported findings in a study of "mixed" dusts and "protector" dusts which he is conducting under a grant from the Foundation. His investigations show that the mixing of inert dust with quartz seems to retard incidence to silicosis. While many substances may act as inhibitors, not all of them are equally effective. When the proportion of silica reached 50 per cent. or more of the mixture prolonged contact with tissues may ultimately cause fibrosis. Early observations of metallic aluminum and the hydroxides of aluminum and iron indicate that each of these substances may be more potent in protective effects than numerous other minerals examined in the tests.

R. H. O.

Lack of Vitamin A in Diet Greatly Restricts Vision; May Cause Auto Accidents.—Finding that persons living on a diet deficient in vitamin A were subject to night blindness, or inability to see in dim light, scientists of the Bureau of Home Economics by studying the adaptation of these persons' eyes to darkness have been able to determine how much of the vitamin the body needs daily. Common sources of vitamin A are yellow and leafy green vegetables, egg yolks, whole milk, orange and tomato juice. Under the direction of Dr. Lela E. Booher, and assisted by Elizabeth Collison and Elizabeth Hewston, five Bureau staff members—two men and three women—consented to an unusual experiment in which all food they ate for six months was prepared in the laboratory kitchen. Literally every bite of the food was weighed to be sure that each one was receiving an ample and constant supply of calories, protein, fat, calcium, phosphorus, iron, and all the known vitamins except vitamin A, which was kept as low as possible. The subjects neither lost nor gained weight and, except for the night blindness, appeared healthy throughout the experiment. The results suggest the possibility that persons who habitually live on a low vitamin A diet may be the cause of many automobile accidents occurring in the dim dusk of twilight, or after dark when drivers stare into the bright lights of approaching automobiles and do not regain normal vision. Low

vitamin A diets not only cause night blindness, but also narrow the field of vision. Even in daylight persons on such diets would not have the proper side vision to prevent them from cutting into cars running by their side or to enable them to see cross traffic approaching when near intersections. At night they are less likely to see pedestrians walking at the side of the road.

R. H. O.

Natural Gas Makes an All-Year Ice Rink.—(*Gas*, Vol. XV, No. 1.) "The tropical ice garden" is the cleverly anomalous name chosen for a new amusement venture in Southern California causing not a little stir in the refrigeration world. Situated in Westwood Village, 10 miles west of Los Angeles, it offers an ice skating rink built out-doors. Its backers insist that they will be able to maintain ice for skating the year around. The rink has been open and operating for over a month and already, thanks to the unusual weather when the official thermometer in Los Angeles reached an unprecedented peak of 92 degrees, the refrigeration system's ability to maintain ice under adverse conditions has received a pretty thorough test. One day the ice itself registered 28 degrees F., one foot above the temperature was 100 degrees and at 2 feet the temperature was 124 degrees. The project represents a bold departure from past artificial refrigeration practice; yet no new principles are involved. Anhydrous ammonia and brine, are employed as refrigerants. The brine however, is not injected into the usual network of pipes laid over the floor. It is collected in a 12 in. header which runs along the side of the rink, and distributed into a series of cells four feet wide and the width of the rink long. These are made of steel plates and laid so as to form a continuous surface over the whole area of the rink, bringing the entire body of the ice in direct contact with the refrigerating surface all the time. Natural gas engines were chosen to furnish power for the ammonia compressor units. There are two 200 hp. twin horizontal engines directly connected to 10 × 20 in. ammonia compressor cylinders. Each unit has a capacity of 182 tons of refrigeration at 25 lbs. per sq. in. suction and 155 lbs. per sq. in. discharge pressures.

R. H. O.

Beach Erosion Studies.—The science of beach protection is comparatively new in the United States. The rapid growth of seashore resorts and the immense investment therein since automobiles and good roads have made them easily accessable have resulted in a demand for improvement and stabilization of old beaches, and de-

velopment of new ones. In the past, as each seaside resort developed, local judgment determined the proper method of improving and stabilizing its beach. There resulted a wide difference in character and design of protective structures. Some have proved effective, others have been useless, and still others have done more harm than good. EARL I. BROWN in the *Proceedings of the American Society of Civil Engineers*, Vol. 65, No. 1, offers in some detail items of information considered necessary in a comprehensive beach erosion study, the reasons for desiring each particular item, and some general observations on design of protective works. They reflect the experience gained by the Beach Erosion Board, United States War Department. It is pointed out that each locality presents a different problem. There are nine principal items for investigation in considering the past history of a beach: geology; shoreline changes; offshore changes; wind records; storm effects; type of protective works installed and their effectiveness; volume of sand moved under different conditions; tides; and predominant direction of littoral drift. A plan of field work should consider the character of the beach and off-shore area; currents; tidal prism of inlets; wave direction, velocity and height during current and sand movements; wind conditions; sand analyses; and periodic areal photographs. Considerable research and study remain to be done before the problem of beach protection can be reduced to a definite science.

R. H. O.

Some Practical Observations on City Traffic.—(*Civil Engineering*, Vol. 9, No. 1.) In a paper presented before the City Planning Division, American Society of Civil Engineers, recently, ELWIN G. SPEYER stated that as a result of his studies as adviser to the police department on traffic matters in the City of Buffalo, N. Y., and elsewhere, he has come to believe that the four most serious problems in municipal traffic control today are: (1) Continual conflict of authority between city government and the police department. (2) The pedestrian's desire to travel the shortest distance between two points. It is inherent in the training and experience of the American people to seek to accomplish a job as quickly as possible, with the least amount of effort. Here education backed by as little enforcement as possible will eventually create an alert pedestrian seeking to travel the safest way. (3) The much too frequent attempts of automobile drivers to start today and arrive yesterday. Manufacturers of automobiles and those in control of traffic are constantly subjected to pressure from the public to produce respectively faster vehicles and streets adapted to greater speeds. Over 90 per cent. of

the fatal accidents today are chargeable to too much speed, and not to a lack of safety devices on vehicles. (4) The unexplained and inhuman conduct of the average automobile driver. It is a rather sad comment that the average individual, courteous and considerate though he may be in the ordinary pursuits of life, when seated behind the wheel of a car becomes a selfish, egotistical tyrant. It would seem that the only help here would be a closer application of the Golden Rule.

R. H. O.

Los Angeles Engineers Urge Earthquake Study.—(*Engineering News Record*, Vol. 122, No. 1.) Formation of an institute for engineering seismological research is urged in a report sent to executives of the American Society of Civil Engineers by the Los Angeles chapter. The chapter's recommendations are based upon the findings of a committee which points out that "the study of engineering seismology is handicapped by lack of positive leadership, insufficient data and absence of authoritative interpretation of existing studies." Under these circumstances, the design of structures in earthquake areas has often led to unsafe construction or to unduly expensive protection against earthquakes. The committee recommends that an institute be set up which could maintain an advisory scientific council before which problems in seismology might be placed for study and decision and which could coördinate study and research throughout the country. The institute also would assemble in convenient form literature on the subject and establish a laboratory prepared to supervise tests of materials of construction.

R. H. O.

Industrial Instruments and Changing Technology.—A Works Progress Administration National Research Project report by G. PERAZICH, H. SCHIMMEL and B. ROSENBERG issued recently describes the history, function, and economic effects of measuring, recording, and controlling devices in industry. In it there is stated that the installation of industrial instruments results in changes in the specifications for available jobs. Skilled workers are eliminated or the number of skilled workers is reduced when instruments serve to standardize or eliminate specialized operations. When instrumentation renders an entire process automatic or continuous, jobs in all categories of skill may be eliminated. The types of instruments sold, as well as the new instruments placed on the market, indicate a shift from manual to automatic control of industrial processes. In 1923 less than 8 per cent, of the instruments sold

were of the automatic-control type, but in every subsequent year the proportion accounted for by this type increased, so that by 1929 more than one-fifth were of the controlling type, and by 1935 about one-third of all instruments sold were automatic controllers. Half the new instruments placed on the market in 1934–37 were controllers. However, many new industries and older industries whose basic production methods have undergone a major change depend upon instruments for their existance and smooth operation. Some chemical industries, for example, are founded on processes which could not be used on a commercial basis without instruments adapted to accurate measurement and maintenance of operating conditions. Thus, although industrial instruments have in some instances served to displace labor, they have also played an important role in the development of such new servies or products as air conditioning, radio, plastics, automobiles, and airplanes.

R. H. O.

Technical Progress and Social Development.—K. T. COMPTON. (*Electrical Engineering*, Vol. 58, No. 1.) Technology has made enormous contributions to modern society, but there still remain many aspects of the influence of technical progress upon social development which challenge attention. Four of these are discussed briefly. (1) The Bogy of Technological Unemployment. When industry is observed as a whole, technological unemployment is a myth, because statistics show no decrease of the gainfully employed in which machine production has become important. In individual instances it may be a very serious social problem and here, two principles should be guiding. Improved products and services should not be stopped to protect any entrenched business or any group of workers. The change should be made in a manner to afford generous protection to the workers affected by it. Various methods are available for reducing the shock of technological changes. (2) Technological Progress and Culture. In discussing the influence of technical progress upon social development there is a natural tendency to emphasize only the material products of technology, forgetting that social development is more an intellectual and spiritual than a material process, and overlooking the influence of technology on the cultural aspects of society. In this sense technology has provided additional tools for the disposal of man, and has afforded the necessary time and facilities for cultural development. To some extent these opportunities have been utilized advantageously but their fuller use is a challenge to management as well as to education and religion. (3) The New Demands on Technology. Better technical development and better management can realize work for the unem-

ployed, profits for industry, new uses for agricultural products, wise use of natural resources, curtailment of natural hazards, better health and comfort, etc. (4) Principles of Management. Experience, logic, and human psychology all support the view that the type of management is most likely to be successful in the long run which directs and inspires but does not too rigidly control, which offers large opportunity for initiative and for criticism, and which has faith in the mass judgment of an intelligent group and in the genius which may appear in unexpected quarters.

R. H. O.

Federal Chemists Produce Noncrystallizing Rosin.—Production of a new noncrystallizing gum rosin has been announced by the Bureau of Chemistry and Soils of the U. S. Department of Agriculture. The new product, a natural rosin obtained from pine gum, does not crystallize in ordinary usage. Crystallization of rosin is a serious problem as it makes the use of rosin objectionable in some industries, particularly those making adhesives, core oil, soap, and paper size. Crystallized rosin reacts slowly with alkali and other materials and forms a granulated product instead of the smooth soapy emulsion desired. Even rosin that has a latent tendency to crystallize may be undesirable. The new rosin is made only from the liquid part of the gum. Its preparation is based on a recent finding by Bureau chemists that the semi-solid mass which forms when the gum is allowed to stand contains most of the crystallizable material. This mass is removed from the liquid part by straining or filtering through a light-weight muslin cloth. The straining takes from 24 to 48 hours as it must be done entirely by gravity. Pressure filters cannot be used as the high pressure would cause the semisolid crystalline mass to liquefy and mix again with the noncrystalline liquid. The straining removes the crystalline part of the resin, and also cleans the rosin by removing chips, bark, and finely suspended particles. Semiplant scale tests have shown that production of the new rosin is commercially feasible. A public-service patent covering the new product has been applied for.

R. H. O.

Wood Waste Used for Marketable Plastics.—Sawdust and other wood waste—often a disposal problem and of little value to the mill operator—may find a profitable use as the basis of a cheap and sturdy plastic material which may be made into many useful and attractive articles. At the Forest Products Laboratory, Madison, Wis., scientists of the U. S. Forest Service have developed and patented for public service a process for converting the waste into a

marketable plastic. Mill waste gets its plastic qualities from lignin, the organic substance that cements and reinforces the cellulose fibers of all trees and plants. Pure lignin forms a brittle plastic that needs a fibrous material to strengthen it. The wood itself furnishes this fiber in the form of cellulose. The hardwoods with which the laboratory has experimented—maple, oak, and hickory—contain 20 to 30 per cent. of lignin. Some work with softwoods indicates their suitability as well. Under the newest process wood waste is mixed with its weight of water and 20 per cent. of its weight of aniline, placed in a metal container and held at steam pressure of 160 pounds for 3 hours. When washed of excess aniline and soluble matter the product is ready for molding with the use of water only. Up to this stage the molding powder should be produced for 3 to 4 cents a pound. The finished material receives a high polish in the mold. It is opaque black in color, although it may be painted, enameled, or lacquered for any desired surface color. It may be turned on a lathe, sawed, or bored.

R. H. O.

Scratched Window Panes Cut Dust Explosion Loss.—Dust explosions in industrial plants in the last 20 years have caused the loss of more than 300 lives and more than $35,000,000 in property damage. Greatest loss of life and property results when dust explosions occur in tightly constructed buildings. Then the terrific pressure literally tears down the structure to escape. The secret of lowering personal injury and property damage where dust hazards exist, is in making allowance for the rush of air to escape should an explosion occur. In old structures where it is expensive to build in air vents, HYLTON R. BROWN, dust explosion specialist of the U. S. Dept. of Agriculture, suggests scratching the outer surface of the windows. A scratch is made from the top corner of each pane to the opposite bottom corner. Each scratch extends to within 2 inches of each corner and skips 2 inches in the center of each pane. These cuts allow the glass to break outward at such low pressures that the exploding dust cannot blow down the walls. The panes are still strong enough to withstand a heavy wind from the outside. The scratches may be cut with a diamond cutter or an ordinary steel wheel glass cutter—just enough to cut the surface. The lines cut with the diamond cutter generally are superior as it makes a smooth, even cut. Unscored window glass of the quality generally used in factory construction is much too strong to give way to the force of the explosion. The window frame itself generally will blow out before the glass will break.

R. H. O.

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